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1929—1930.

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THE ASSOCIATION was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of 800 men. Its membership is divided into six classes, viz.:

A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

A Life Member shall be a member whose service to the Association entitles him to special recognition by the Association.

A Junior shall be not less than eighteen years nor more than twenty-five years of age, a student or connected with water supply work.

An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

The initiation fees and annual dues are as follows:

	Initiation Fees		*Annual Dues*
Members	$ 3.00	Members	$ 6.00
Juniors	1.00	Juniors	3.00
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This Association has six regular meetings each year, all of which, except the annual convention in September, are held at Boston.

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HISTORY OF THE ORGANIZATION OF THE PORTLAND WATER DISTRICT.

BY DAVID E. MOULTON.*

[*Read September 17, 1929.*]

We must go back a number of years in order to understand the present organization of the Portland Water District. The Portland Water Company was incorporated in 1866. Its charter provided for $1 000 000 of capital stock, all of which was to be devoted towards supplying water to the city of Portland. No charter could have been framed to better protect the interests of the public. According to its provisions the city could at any time purchase up to 50 per cent. of the capital stock at cost plus 10 per cent. It also provided that the Water Company should furnish water free of charge forever for all strictly municipal purposes, for the extinguishment of fires and for the use of public buildings in the city. To this day this obligation has been lived up to by the Portland Water Company and its successor, the Portland Water District. Of course there is really no such thing as free service. What one department receives free of charge others pay for, as water-works men know. With misconceived zeal to protect the public interest, however, this provision was included in the charter. The charter provided for a water commissioner whose duty it was to see that the Water Company lived up to its obligations. The courts were given equity power to enforce the contract, and by an amendment at a later date the city was authorized to take over the properties at a valuation any time after six years.

In spite of these precautions, only $800 of the original stock issue of $1 000 000 which was fully subscribed was actually paid up. The balance was to be paid upon demand, but payment was never required. No provision was made in the original charter for a bond issue, but after the promoters had tried for two years to get the city to practically underwrite the works, they went back to the Legislature and secured authority to issue $800 000 worth of bonds. These bonds were sold at a substantial discount, and the promoters voted themselves each a salary of $2 000 out of the proceeds of the sale, not being content with getting all the stock without payment. The promoters next made a contract with out-of-state people to build the works. These were improperly constructed, a hump left in

*Clerk and Attorney of the Portland Water District, Portland, Me.

the conduit producing a poor hydraulic gradient. Burdened with these deficiencies the company soon got into difficulties. Later the promoters voted that any person who held certificates of stock, callable and payable upon demand of the treasurer, might, if he saw fit, surrender these certificates and receive in return certificates marked "fully paid and non assessable." Naturally all stockholders made the exchange. The company was soon practically bankrupt; it could not pay its bills, and a reorganization became necessary.

At this stage local parties took the matter in hand, secured authority to issue more bonds and called in part of the stock, which was issued as a bonus to help out the bond issue. In this manner the company was placed on a sound financial basis. I don't know whether the public was acquainted with the situation so that it could buy the bonds with the stock bonus, but if it was, there certainly could not be a complaint that the people who took the chance made a profit. Subsequently, it appeared that on the original investment of $800 paid for the $1 000 000 par value of stock, the citizens of Portland paid in dividends $1 750 000. This seems to have been a reasonably good return on the investment.

At a later date, when it became necessary to extend the system into adjoining towns, a new company was organized. Part of the old company's system was sold to this new company, although the system was still covered with the mortgage bonds. New works were constructed in Cape Elizabeth and South Portland and $700 000 worth of stock of the new company was issued to the old company in payment for supplying water to the new system. This stock was distributed as a dividend to the old stockholders.

With this type of financial manipulation, water rates were naturally high. It is interesting to note that the first rates were made on the basis of the municipal valuation of property. A property valued at $5 000 paid more for water than one valued at $1 000. Rates were so high that the people objected. An investigation was ordered, and court proceedings were instituted to examine the books of the company. Reluctant to have its books opened, the company arranged a compromise; but agitation ensued for municipal ownership.

Throughout this period there had been a constitutional provision in Maine that no municipality could issue bonds or incur debts in excess of 5 per cent. of its valuation. Hence it was out of the question for the city to take over the company's properties. In order to stifle newspaper opposition an ingenious innovation was made by the company. It created a voluntary sinking fund which permitted setting aside certain funds out of the annual income. These sinking funds were then invested in stock in the daily paper that was calling for a reduction of rates. This constitutes briefly the background for the demand for municipal ownership.

In 1899 a bright young lawyer named Harvey Eaton conceived the idea that the constitutional debt limit applying to any city or town no more applied to a new municipal corporation made up of several cities or towns

than it did to the debt of the county or state. Based upon this principle the Kennebec Water District was created, for a group of other Maine communities, and the Supreme Court finally decided that there were no barriers to municipal ownership in this form.

In 1902 a committee of the city government was, therefore, appointed to investigate the advisability of a similar water district for Portland. It made a splendid report but, as the company refused to show its books, no estimate of the cost of taking over the plant could be made. The matter became a political issue. The Democratic candidate for mayor came out frankly in favor of municipal ownership through a water district and invoked a referendum. The Republicans remained lukewarm, advised caution and suggested a new contract with the Water Company. As a result the city, normally Republican, went Democratic. It voted three to one for a water district, and three to one against having any more contracts with the Portland Water Company. With the prestige of this election to support them, the Democratic city government went to the Legislature in 1907 and secured a charter for the Portland Water District.

After a vain attempt to agree on terms of purchase the property was taken by right of eminent domain. There were five companies to be appraised, — the old Portland Water Company which had sold part of its mains between the city and Lake Sebago to a new company; the new company which owned a part of the supply mains and furnished water to other parts of the territory; the Foreside Company which distributed water to Falmouth and Cumberland, its entire capital stock having been issued for the water supply; the Gorham Water Company supplying the town of Gorham and the Munjoy Land Company, holding real estate in Portland and South Portland. These companies were so interconnected that valuation of their properties was a difficult problem.

It was necessary to retain good engineers to determine the value of the properties. Among them may be mentioned Hazen and Whipple, Metcalf and Eddy, John R. Freeman, and E. V. French. Recording gages were installed, and when the worst fire in many years destroyed the City Hall, our engineers had an excellent record of the value of the system.

In the meantime, most of the correspondence and contracts with the city had mysteriously disappeared from the files of the city. We, therefore, spent three months working through the files of the newspapers, and read every article published within sixty years that had anything to do with the water supply. When we finished we had a copy of every contract that had ever been entered into, and everything that had ever been proposed. Although these documents were not part of the records of the city they were available for the trial. We investigated the title to Lake Sebago from the time the Indians owned it. Although we did not find their surrender of the title, we discovered evidence of the King of England giving the lake to the Massachusetts Bay Colony. When we got into the trial we found the Water Company claimed $100 000 for a contract purporting to control

the height of water at the outlet dam. Our search, however, showed that they did not have any right to such control; our study had been worth while.

The companies claimed $5 000 000 for the properties; we claimed they were worth less. One of the appraisers in the case was Judge Savage, afterwards Chief Justice, who wrote the opinions in the Brunswick and Topsham water cases that laid the foundation for the valuation of utilities; another was Associate Justice Powers. Herbert Heath, of Augusta, an attorney who had represented the Water District in securing its charter, appeared for the Water District; and Orville Baker represented the water companies.

The final award was a little less than $4 000 000, but the fees of engineers and lawyers brought the cost to that figure. At that time the gross income of the system was $300 000 a year, and there were about 200 miles of mains in operation. The people were afraid of the future of the district. Westbrook, which had the opportunity of joining the district, voted five to one to stay out and avoid the hazards of municipal ownership. Thus the district consisted solely of Portland and South Portland.

We issued temporary loans at 3½ per cent. and later replaced them with bonds at 4 per cent. A new supply main had to be constructed because the system was outgrown and there was no fire reserve. The new main cost about $1 000 000. After its construction and financing, we found we could make a reduction in the water rates of about $20 000 a year, and fire insurance dropped $35 000 a year. We also gave a 10 per cent. discount for payment of water bills within 15 days. This practice we kept up until war times, when we dropped the discount to 5 per cent. We next assumed the expense of installing and re-running all services in the streets to the property line and maintained the services, whereas the old water company had required payment for them by the water takers. The minimum meter rate was reduced from $12 to $10 and the flat rate from $6 to $5 for the first faucet.

Early in our existence we started buying land on the shore of Lake Sebago to protect the water supply. When we took over the system there were within 1 000 ft. of the intake, cottages with old-fashioned toilets that were flooded at high water. There were lake steamers carrying hundreds of people, and the steamer toilets emptied directly into the lake. All of this was corrected. We continued to spend money on improving the system, until the $4 000 000 plant that we took over had increased in value to over $8 500 000. The district expanded quickly 12 miles to the east and 12 miles to the west.

We set aside a sinking fund of one per cent. per year of our indebtedness, and when our bonds matured a year or two ago we had $1 650 000 in our sinking fund. Over $2 000 000 of our bonds have been retired in 20 years, or an average of $100 000 a year.

Counting the saving in insurance rates, the re-running and installation of services and the reduction in water rates, the total saving amounts to

$100 000 a year. In addition the city receives for municipal purposes and fire protection about $100 000 worth of service.

May I end with a quotation from a statement by the late Frederick P. Stearns which seems to fit the accomplishments of the Portland Water District most appropriately. "I believe if any city had a system by which the public works could be wisely, prudently, and honestly ordered, constructed, and maintained, it would nearly have solved for itself the vexed problem of municipal government."

A DESCRIPTION OF THE SYSTEM OF THE PORTLAND WATER DISTRICT.

BY JAMES W. GRAHAM.*

[*Read September 17, 1929.*]

Historical. The history of the Portland Water District may be traced to days before the war of 1812 when William Freeman laid the first water pipe in Portland from Neck Pond on Munjoy Hill to the more thickly settled parts of the town. This lead pipe, poor in quality and very thin, was rendered useless in a short time, and the enterprise proved a total loss. Later water was supplied through log pipes from a reservoir near the head of Hancock Street to families in the lower part of the city. These works were owned by Captain William Woodbury and others, who finding it difficult to furnish a satisfactory supply of water, leased the works to the Atlantic and St. Lawrence Railroad Company in 1847. This system, too, was soon abandoned and until the introduction of Sebago water in 1869, householders were dependent on wells and cisterns. To provide water for fire fighting the city built large cisterns in different parts of the town. At times the shortage of water was very acute, and many schemes were proposed for obtaining a public water supply. These plans were earnestly debated until a good rain storm had filled the cisterns; then the subject was forgotten till another drought occurred.

The first record of interest by the city government dates back to 1849 when a committee was appointed to inquire into the matter of a better water supply, but no action was taken. Scarcity of water during the drought of the summer of 1854 caused great anxiety, and on September 17 of that year, a petition was presented by Woodbury Storer and others requesting the city government to inquire into the cost of bringing water from Sebago Lake. It was found that the cost of this enterprise would be nearly four million dollars. This sum was considered beyond the resources of the city, and the plans did not materialize.

In February, 1866, a petition was sent to the State Legislature for authority to bring water into the city from Long Creek, and the Portland Water Company was incorporated on February 23, 1866 to perform this task.

The great fire of July 4, 1866, which destroyed a third of the city, while interrupting proceedings, furnished a strong argument for hastening construction of the works. In 1867, the charter of the Portland Water Company was amended and granted authority to go to Sebago Lake for water. Not until a year later, however, did the city government decide to enter into a contract with the company to provide a public supply for the city.

*Treasurer and General Manager of Portland Water District.

On April 29, 1868, work was commenced on the conduit at the lake; on May 4, ground was broken at Saccarappa (now Westbrook) for laying a 20-in. cement main; on August 11, the first distribution pipe was laid in the city, on Cumberland Avenue; on May 19, 1869, construction of the Bramhall Reservoir was started; and on October 13, the company announced that it had laid 32 miles of pipe and that the reservoir was completed. Unexpected difficulties in making rock cut through which the conduit had to pass, however, delayed the introduction of water from the lake, and in order to test the supply main, water was obtained from a small brook near the lower gatehouse. Water began to flow into the reservoir at 11 o'clock, November 18, 1869 (Thanksgiving Day), and on November 26, water was let into the Congress Street main and filled all the pipes in the city. Finally on July 4, 1870, four years from the time of the great fire, it was announced that the water works were completed. The system included a 20-in. main from Sebago Lake to Portland, a reservoir on Bramhall Hill with a capacity of 10 m.g., and distribution pipes in the principal streets of the city.

Sebago Lake—the Source of Water. Sebago Lake, then, as today, the source of Portland's water supply, is located near the center of the Presumpscot River basin lying between the Saco and Androscoggin rivers. Its distance from the city is 17 miles. The drainage area including water surfaces is 436 sq. miles. The area of water surfaces is 71.5 sq. miles of which Sebago Lake constitutes the major portion (45.6 sq. miles). There are 38 other lakes and ponds with a combined area of 24.4 sq. miles, and the area of undrained swamps is 4 sq. miles. The elevation of the lake surface is 272 ft. above mean low tide, and the lake is said to be 350 ft. deep in spots.

The lake water is soft and contains little organic matter. The lake is fed by mountain brooks and streams and is large and deep enough to protect the supply against contamination. In its natural state the lake water is clear and unpolluted. To further safeguard its purity, however, the district has acquired two islands near the intake on which were located a number of summer cottages. In addition, nearly all of the shore front of the lower bay has been purchased, or is controlled by the district by agreement with the owners. The district has expended more than $225 000 in purchasing this land comprising about 600 acres. On a large part of this tract white pine has been set out, more than 125 000 three-year old white-pine transplants being used.

In 1913 a law was enacted to protect the purity of the waters of Sebago Lake. Under this act "no cottage, or other structure, to be occupied by man or beast, can be built within 200 ft. of the shore of the lake, and no person, firm, association, club or corporation shall use or occupy any structure upon or near the shore of Sebago Lake, or any of its direct tributaries, in such a manner that the sewage or drainage therefrom shall enter the waters of the lake or any of its direct tributaries to pollute the same." The act further provides that bathing is prohibited within two miles of the intake.

In order to carry out the provisions of the law, it is necessary to main-

tain a motor boat and shore patrol, and a rigid inspection of all camps and cottages. The cottage owners, almost without exception, show a willingness to coöperate with us in maintaining the purity of the water.

A new source of danger has arisen in recent years from automobile camping parties that often trespass upon the shore of the lake, making overnight stops. This is more difficult to deal with.

A fully equipped laboratory is maintained, and daily tests are made on water samples from the lake and other parts of the distribution system. The results of the tests of the lake water are most gratifying. They show a steady reduction in pollution and justify the expenditure that has been made in purchasing land and patrolling the watershed.

As a further safeguard against chance pollution a liquid chlorine plant is located in the gatehouse at the head of the main pipe lines. The average chlorine dosage is 1¼ lb. per m.g. and the water is practically sterile when it enters the mains on the way to the city.

Intakes and Pipe Lines. The original intake consisted of a screened box on the lake shore. From this point 5 470 ft. of conduit were built through the rocky rim of the lake. This conduit consisted of a section in tunnel 6 ft. high, 3 ft. wide and about 750 ft. long, cut through solid rock, and a section in open cut from 10 to 28 ft. deep, lined with brick.

It developed later that the contractors had not performed their work faithfully. The rock through which the conduit was built had been left some 3 ft. above grade. This situation became a constant source of trouble whenever the water in the lake was low. Some improvement was made in 1880, but a bad hump or high section of some 18 in. remained.

In August, 1892, 480 ft. of 48-in. cast-iron pipe were laid from the intake at the shore into the lake. This extension ended the clogging of the intake screens with leaves and other material floating on the lake surface.

The hump in the conduit naturally reduced its carrying capacity. As the demand for water increased from year to year, the situation eventually became serious. In 1902, to overcome the difficulty a reservoir known as the "Basin" was, therefore, built at the lower end of the conduit with a capacity of 9 m.g. This helped out for many years, until the consumption of water in Portland and the other towns supplied again reached a point where the capacity of the conduit became inadequate during the low-water stage of the lake. At normal low water the conduit carried about 11 m.g.d., while the maximum flow to the city reached 16 m.g.d. and the night flow 9 m.g.d., the fluctuation being taken up by the Basin.

In 1923 work was, therefore, commenced on new intake works with a capacity of 75 m.g.d. A reinforced concrete pipe 54 in. in diameter and 1 580 ft. long was extended into the lake from a gate- and screenhouse at the lake shore. The pipe terminated in a bellmouth 26 ft. below mean lake level. The gate was connected to the existing supply mains by a cement-lined tunnel 60 in. in diameter, 1 900 ft. long, and a 54-in. reinforced concrete conduit 1 900 ft. long. The total cost of this project was $607 640.56.

The original supply main consisted of a 20-in. cement-lined wrought-iron pipe 16 miles long. With the exception of about 5 miles which were abandoned from Douglass Street, Portland, to Westbrook this main, laid in 1868, is still rendering good service. In 1876, four miles of 26-in. cement-lined wrought-iron pipe were laid from the lake conduit to Wards Hill. In 1878–1879, 12 miles of 24-in. cement-lined wrought-iron pipe were added, completing a second main from the lake to Portland. This pipe line is still in service with the exception of about three miles which have been abandoned on the Portland end of the line. In 1902, a 30-in. cast-iron main was built from the lake conduit to Wards Hill, a distance of 5 miles, and connected with the 20- and 26-in. mains. In 1912, finally, a 42-in. cast-iron pipe, 17 miles in length, was laid from the conduit to the city. The combined carrying capacity of these mains is 24 m.g.d., the average daily consumption for 1928 being 12.189 m.g.d.

The Portland Water District. In 1907 the Portland Water District was created. After exhaustive hearings the valuation of the entire properties was fixed at $3 850 034.26 which, with the expense of the hearings, made the total cost of the Portland Water District as of January, 1908, $4 005 678.14.

The district now served covers a distance upwards of 25 miles along the coast. It extends from Cumberland Foreside on the north, through the Deering section of Portland to South Portland, Cape Elizabeth, Higgins Beach and Prouts Neck. It also serves areas further inland on the south, extending through Scarboro to the city of Saco line. Between Sebago Lake and the city of Portland the district supplies, furthermore, the towns of Gorham and Windham, and the city of Westbrook. To this territory must be added three islands in Casco Bay. The total population served is about 105 000.

In 1928 construction work was started on a new service building for the Water District. The building, located on Douglass Street, was completed in December of the same year. The structure is a distinct departure from buildings of this nature by combining beauty with utility. Thus it is an asset rather than a detriment to the neighborhood. In the rear of the building there is ample yard room with side track accommodation for the storage of pipe and other materials, also underground storage for 20 000 gal. of gasoline and 500 gal. of fuel oil. The total cost of the plant including land and equipment was $160 000.

A summary of the system operated by the district may be given as follows:

Pipe lines and distribution mains	376.25 miles
Combined storage capacity of three reservoirs	38 000 000 gal.
Combined storage capacity of six standpipes	3 016 000 gal.
Average daily consumption	12 189 000 gal.
Population supplied	105 000
Regular employees	58
Average daily consumption per consumer	105 gal.

Inhabitants per mile of mains	278
Hydrants	1 762
Gates	2 406
Services	19 871
Services per mile of mains	58
Meters	9 816
Services metered	49 per cent.
Net cost of work January 1, 1929	$8 499 794.50
Bonded debt January 1, 1929	$6 165 000.00
Total revenue for 1928	$571 969.56
Total operating expense, interest charges and sinking fund payments	$558 818.67
Bonds retired through sinking fund	$2 034 000.00

Operating Equipment. The policy of the Water District Trustees has been to carry on the operation of the district by use of modern equipment. When the plant was taken over in 1907, the construction and maintenance work was being done by the use of three teams. Today, 18 automobiles and trucks are being used. While the operation of this fleet is somewhat expensive, it has resulted in giving prompt attention to troubles and complaints. In order to further care for emergency troubles, an emergency service truck is now being used. (See Fig. 1.)

The truck consists of a 1½-ton Graham Brothers truck. On each side is a tool box running the full length of the body, which also serves as a seat to carry extra workmen when necessary. In the tool boxes are carried implements such as picks, shovels, wrenches of various types, rubber coats and boots, gate books, electric hand lamps and extension cords, jacks, and tow lines. In fact, all tools necessary to handle water-works emergencies, such as breaks on main lines, distribution mains and hydrants, are included. The jacks and tow lines are used for assisting passenger automobiles, or trucks, which have become stuck in soft trenches or have run into open trenches. The truck is also equipped with a Kohler & Kohler 2 000-watt automatic electric generating plant. The generator is capable of operating three 250-watt searchlights and several hand lights. It can also drive a ditch pump with a capacity of 70 g.p.m. against a head of 20 ft.

The truck is used for all emergency work and responds to all second-alarm fires within the territory supplied by the district for the purpose of closing gates in case of breaks on mains or hydrants. It also assists the fire department with flood lights when desired. Within the past month of August, 1929, this truck responded to a general alarm fire where a loss of more than $500 000 was involved. For several hours its flood lights greatly assisted the firemen in their work. On several occasions the truck has been used on night emergency work, and the lights have greatly assisted our workmen. The total cost of the truck with equipment was $2 000.

In 1926 the district purchased a Barber-Greene trencher at a cost of $5 750. This machine is employed wherever the size of the job warrants its use. During the year 1928–1929 this machine dug about 5 miles of trench

at an average rate of 68 ft. per hour, the average cost of trenching for the year being 21 cents per ft., as compared with an average cost of hand trenching of 23 cents per ft. The largest day's work done was 1 800 ft. at a cost of 14 cents per ft.

Extension of System. Little by little the distribution system of the district has been extended and improved to meet the growing demands of

FIG. 1.— EMERGENCY TRUCK OF THE PORTLAND WATER DISTRICT.

service and fire protection. In addition to the new supply main and conduit, the system has been strengthened by additional pipes involving an expenditure of over two million dollars, none of which was necessary for the domestic supply. All these improvements have resulted in a much improved system, and when a demand for 30 fire streams was made at a recent fire, the water was available with a drop in pressure of only 10 lb. per sq. in. This experience stands in marked contrast to that of the great fire which destroyed the city hall in 1908. On that occasion with only 21 fire streams in use, the pressure was so reduced that no water would have been available for a fire in the higher sections of the city.

In 1928 the National Board of Fire Underwriters made an extensive survey of the system, and the Portland Water District was found to meet the requirements of a Class A rating.

BEAUTY — AN INVESTMENT.

BY JOHN CALVIN STEVENS.*

[*Read September 17, 1929.*]

When I say that beauty is an investment I know your first thought will be that this statement relates to an expenditure of money which will bring a return in dividends equal to, or better than, the usual one; but there are dividends of spiritual as well as of monetary value. A wise investment will return both kinds to you.

An architect is always anxious to have his creations properly placed in attractive surroundings, but too often, even when the opportunity is favorable and funds are available, the grounds of prominent and public buildings are left unkempt, and uncared for. This although it is a well known fact that the proper plainting of vines, shrubbery, and trees can so transform an ugly building that it becomes attractive, while a building, interesting in itself, will possess increased beauty by the proper planting of growing things.

A city is not only a place in which to do business; it is also a place in which to live, and everyone desires to live pleasantly and happily. One way to bring about this very desirable condition is to have all the city's institutions so built and cared for that they become landmarks of interest and beauty.

Often sites which seemed beyond improvement have by study and good sense been made attractive at small cost.

All who are interested in water-works development know that the American Water Works Association has for some years been engaged in a study of the advantages to be derived from improved architectural development of utilitarian buildings and the treatment of their grounds.

One of the early examples of a water works designed with the idea of creating a beautiful plant is the old water works of Philadelphia, built in 1801. It consists of a classic group of buildings and is very attractively situated. A few years ago the city of Philadelphia wanted to construct a broad avenue from City Hall to Fairmount Park and make available sites for the new Art Museum and Public Library. The plan contemplated the practical elimination of the old water works. Joseph Pennell, a native of Philadelphia, and one of the greatest artists this country has produced, however, made vigorous protest, stating that he considered the old water works the most artistic and attractive spot in Philadelphia, and that its loss would be nothing short of a crime.

Those who have admired Pennell's drawings of old Philadelphia are bound to agree with him, and it is a pity that these examples of beauty could

*Architect, Portland, Me.

not have been retained. The buildings still stand, but the beauty of their surroundings is gone forever. We are impressed by the fact that this beautiful group in its picturesque setting was a distinct asset to the city of Philadelphia, and thus had justified the thought and care given to its artistic development.

It seems evident that any public body is acting wisely when it decides to make its holdings attractive, and gives due consideration to the effect upon surrounding property. Good business demands consideration of these points, and fully warrants reasonable expenditures for the purpose of enhancing the beauty of its plant.

Commercial buildings and factories are now being built with an eye to attractiveness of appearance, and the hard-headed business man who once saw nothing in Art is realizing the advertising value of such an investment. Not only are the buildings being made more attractive, but the grounds which provide the setting are planted with shrubs and trees to complete the picture and attract the passerby because of the beauty thus created.

It has been shown that the additional cost of making a strictly utilitarian structure architecturally interesting is a very small percentage of the total cost. Without sacrifice of efficiency or convenience in the plant, the additional expense needed to provide interest and beauty need not be over 5 per cent. of the total and in many cases will run as low as 2 per cent. This additional amount, in the case of a building prominently situated, is a very small sum to pay for an improvement which affects favorably the value of all the surrounding properties as well as that of the plant itself. Any public or private corporation is, therefore, fully justified in the expenditure necessary to add interest and attractiveness. It is a duty which the corporation owes to the public, as well as to itself.

Business men have observed that customers expect a trustworthy firm to succeed well enough to have the means for erecting a suitable building in which to carry on their activities, and that there is increased confidence in a company which is housed in an attractive building, well situated and well cared for. This practice indicates to the observer not only prosperity but suggests pride in the product produced.

Business has discovered that proper advertising pays. The small amount paid for a better looking building and attractive grounds, therefore, can well be charged to the advertising account and will invariably be found to be a good investment, returning dividends in increased business, and increased good will. The latter is one of the most important assets of all business.

As an example of the advertising value of appearance, may I cite a fruit and produce store in an outlying street of a certain city, a store I passed each day for several months. The store was owned by an Italian who had a keen sense of color combined with good taste. With the same fruits and vegetables displayed by a neighboring shop in the usual helter skelter

manner, this man arranged a most attractive window display, and many would stop to admire his harmonious combinations of color. The returns from his investment of time and taste were a rapid increase in sales, and it was only a short time before he moved to a bigger and more important location, while his neighbor remained.

Another point to be considered is the psychological effect upon employees. A man cannot help being influenced by the character of the building and surroundings in which he must labor every work day of the year. If the place is ugly, untidy and dirty, it will have a depressing effect and he will approach his work not with enthusiasm but with indifference. On the other hand, the enjoyment and satisfaction experienced in a place of work which is attractive and pleasant are uplifting and assist in performing the duties of the day. The amount of assistance is hard to estimate, but is real.

If the beauty of the building and its surroundings give the worker pleasure and contentment, then it is silently and perhaps unconsciously exerting a beneficial influence on him. The result will be a feeling of loyalty among the workers. It is much easier for a man to pledge allegiance to a place which is attractive than to one which is ugly and in which he cannot take pride. Since allegiance to the plant is a very important matter, it is evident that anything which fosters it is of vital and economic importance and can be classed as a good dividend.

I have always contended that every man has the public duty to make his home surroundings as attractive as possible, and it is true that the work of one man who gives some attention to the planting of shrubs and vines and to the character of the grounds around his home has a beneficial effect upon the entire neighborhood. His neighbors will soon begin to follow his example, and the neighborhood will quickly attract favorable attention. All this benefits not only the man who begins, but all his neighbors, and therefore the entire community in which he lives. In these days of rapid transit and communication we are all neighbors.

If this is the duty of the individual, why is it not still more the duty of corporations, whether private or public, to so conduct their building operations that they will benefit the community and increase the value of property, rather than depreciating its value while saving a little money on construction. Such curtailment is not good sense, nor is it good business.

All of us crave beauty and react to color often with marked effect. The average man or woman instinctively prefers things which are really beautiful. This characteristic has not been sufficiently realized; many have felt that the garish and bizarre appeal most strongly, but this is not so. It is the simple, really beautiful things that give most pleasure and are most widely appreciated. In decorating a building or grounds, the simplest forms, if carefully studied, are more likely to fulfill artistic requirements, than the more lavish use of ornament or color. In the planting of grounds, therefore, I advise against over-elaboration, with the sure knowledge that the best results will be obtained by simple and often very inexpensive means.

Too much of a good thing can be cloying, while just enough gives satisfaction and a sense of well being; all this makes for happiness. In its train follow peace of mind, contentment, and a sympathetic approach to one's work and one's fellowman. If then by judicious use of growing things, — trees, shrubs and flowers, — we can bring contentment to men, it is unquestionably a wise expenditure of time and money. Whatever makes for such a condition is a contribution to the community and is a service all men and all corporations should strive to render.

It is not enough to render service through material things; it is essential that there should be service through the spiritual things of life as well.

When water-works men have furnished pure water in ample quantity they have performed a vital service, but their service is incomplete, unless the works have been made as beautiful and attractive as possible and have thus furnished that appeal of higher things which elevate the human being into something more than a money-making machine.

Water is essential to the life of a city, both as regards the health of the people and the protection of property. Every citizen should be vitally interested to know that the water served to him is pure in quality, and ample in quantity to give protection to his property when fire threatens. One sure way to awaken his interest is by making the water-works property attractive.

A public building like that of the Portland Water District would be failing in its purpose if it did not prove to the community and to the world at large that the interests of all the people were given careful consideration, and it was a pleasant experience of the architects who designed it that the Trustees of the Portland Water District were desirous of achieving such a result.

Let us next look at the location of the Portland Water District Shops and consider a type of treatment which could have been adopted. It would have been possible to erect on the lot a substantial building to answer all the working requirements, but no more interesting in appearance than a common storehouse such as might be tucked away on some back lot. With the grounds left to take care of themselves, the effect upon surrounding property would have been to depreciate values very materially, and the owners of neighboring properties would now be condemning the management for shortsightedness, and a general feeling of enmity would have speedily become evident.

Also there would have been a psychological effect upon the citizens because we are prone to look upon any institution which seems to be careless of appearances as one not well cared for in other particulars. In the case of a water-works shop this is an important consideration.

The building which the Portland Water District erected and the treatment of the grounds show the wisdom of the Trustees from a purely business standpoint. (See Fig. 1.) This shop which is placed in a prominent location is seen by many thousands who pass over the adjacent highways each

FIG. 1. — SHOPS OF THE PORTLAND WATER DISTRICT.

year and is bound to attract favorable attention. The effect upon the passerby will be a feeling that if this Water District cares in this way for its shop properties and working departments, it is very probable that it is exercising equal care in guarding the attractiveness and cleanliness of the water. The psychological effect of this means increased confidence on the part of the individual, and completely justifies the slight additional cost. It returns a spiritual dividend of great value and also serves as a big advertising asset for the entire community.

Talking recently with one of Portland's prominent real estate dealers about the new shops, I remarked that in my opinion the plant had raised the value of the surrounding property at least fifty per cent. His reply was terse and to the point, "Fully that." It is evident, therefore, that the Portland Water District has created value not only to the immediate vicinity of the shop but in the entire city. The additional cost of the planting and other embellishments has been very small compared to the total investment.

The tower or spire which forms the focal point of the building is a purely utilitarian feature, but is unlike the usual tower put up for the drying of hose. With proper study it has become an important part of the attractiveness of the building and has been built at a less cost than the usual construction adopted for the same use.

An attractive plant like this is also sure to awaken the interest of the citizens who own it, and to bring about that feeling of pride of ownership of which I have spoken, and instill confidence in themselves because they have, by their votes, selected the right people to manage their property.

The Ideal City should be the aim of every citizen, and he should be willing and glad to lend his aid to every attempt to make the city more interesting, more beautiful, and hence more liveable. Since corporations are nothing more than a collection of individuals, governed generally by a chosen Board of Directors, or Trustees, corporations as such should be as much or more interested than the individual. The individual delegates to the board the power of management and should commend every effort the board puts forth to advance the interests not only of the corporation but also of the entire community. I am sure that the attractive treatment of grounds and buildings will always meet with public approval.

A community that is filled with attractive homes, clean streets, and beautiful public buildings and grounds will grow, perhaps not boom, but grow steadily and substantially.

From the Greeks of old Athens comes our heritage of Art. The world would have been poorer if Athens had not existed. From there we find inspiration of beauty in Architecture, and Sculpture, and the work of those early Greeks has not been surpassed in later times.

There is a story that in ancient Greece when a young man reached maturity he was called upon to subscribe to this oath: "We will never bring disgrace to this our city, by any act of dishonesty or cowardice, nor ever

desert our suffering comrades in the ranks; we will fight for the ideals of sacred things of the city both alone and with many; we will revere and obey the city's laws and do our best to incite a like respect in those about us who are prone to annul or set them at naught; we will strive unceasingly to *quicken the public sense of civic duty; thus in all these ways we will transmit this city not only not less, but greater, better and more beautiful than it was transmitted to us.*"

May it not be that it was a spirit like this that accounts for the beauty and fame of the city of Athens which has come down to us through the ages. If we could each have such a feeling toward our abiding place, what a different world it would be.

I believe that beauty is truly an investment, and I hope I have given a worth while message, though I am sure that the thought is so fully expressed in a poem by Strickland Gillilan that it seems most fitting to quote him:

A garden, a perfect mosaic, deep green 'gainst the blackest of loam,
Spread out near a little log cabin — but immaculate home!
I paused to admire — who could help it? — the weedless expanse near the door.
Where pleased with my pleasured inspection, stood a "Mammy" of years that are yore.

"A beautiful garden," I ventured. She cupped a brown hand to her ear.
"Fine Garden," I shouted. "Oh, Sholy! It ought to be fine — I live here!"
I went on my way with a sermon as great as I ever have heard;
The highest paid preacher existant could never have added a word.

Were every human who cumbers the tiniest spot on the earth
To see that the place he inhabits — the work brain or fingers give birth—
Stood perfect as e'er he could make it — dear God, what a different sphere!
Let's borrow our motto from "Mammy": "It ought to be fine — I live here."

WATCHING THE WEATHER IN SAFEGUARDING PUBLIC WATER SUPPLIES.

BY ARTHUR E. GORMAN.*

[*Read September 20, 1929.*]

To a degree much larger than generally realized by water-works officials are the elements that make up what we call "the weather" responsible for the quality and safety of public water supplies. One has but to review the findings in the many outbreaks of water-borne disease recorded in the health and water-works annals of this and other countries to be convinced that weather conditions have, generally, constituted one of the principal links in the chain of circumstances associated with these epidemics of typhoid fever, cholera and dysentery. What is more, one cannot help being impressed in studying these records by the fact that many of these outbreaks could probably have been prevented, if water-works officials had been more watchful over weather conditions and had consequently been better prepared to cope with resulting emergencies.

Floods or drought, winds or calm, sunshine or cloudiness, heat or cold, freezing or thaw, high or low barometric pressures and tides, all have their influence directly or indirectly on the quality and safety of public water supplies from both underground and surface sources. The classical epidemic at Plymouth, Pa., in 1885, followed a thaw; a summer snowstorm preceded the typhoid outbreak at Soldier Summit, Utah, in 1925; floods marked the beginning of the spread of almost countless epidemics of typhoid and cholera all over the world; freezing of the filter beds allowed infection to reach the consumers and caused the Lawrence typhoid epidemic; drought, with a shortage of water, caused Olean, N. Y., to use an unsafe secondary supply with a sharp outbreak of typhoid as an aftermath; excessive rates of precipitation with flooding of sewers preceded the recent Essex, Ontario typhoid outbreak; southerly and southeasterly winds drifted pollution toward Chicago's water intakes; strong winds following heavy rainfall carried gross pollution across the rapid currents in the Detroit River into the Detroit intake in 1926, resulting in a serious outbreak of dysentery all over the city even though the water was filtered; a few hours of gale and most of the water works of South Florida were out of commission in 1926; torrential rains in the fall of 1927 brought serious damage to water works in western New England.

A cold spell may cause anchor ice to clog the intakes on inland lakes; prolonged sunshine may stimulate prolific growth of algæ with subsequent tastes and odors in most impounded water supplies; a storm on the watershed of some streams may increase the turbidity of the water at the river

*With Wallace & Tiernan Co., Newark, N. J.

intakes tenfold; a hot spell may send thousands of picnickers to seek relief at mountain lakes used for public water supplies — increasing the health hazard of these watersheds; unusual tides may carry pollution up tidal streams to supposedly safe intakes; oscillation of water levels on the Great Lakes due to differences in barometric pressure or high winds may upset the flow in the connecting rivers and tributary streams and may cause serious pollution of public water supplies.

During the last few weeks, many New England cities and towns have sought permission from their state boards of health to use water from secondary and possibly doubtful sources because a prolonged drought has caused a shortage in their regular supply. How many of the officials in charge of these water works have kept adequate records of the rainfall on their watersheds to enable them to predict this shortage and the approximate length of time during which the emergency supply will have to be used? What is more — in how many instances have definite plans been made for the procedure to be followed when the emergency supply is called into use?

Shortage of water in a public supply is a potential health hazard. Every water-works system has one or more weak points regardless of how well it is designed, built and operated. It is encumbent on the directing water-works officials to know these weak links and their probable behavior when subjected to the strains that may be exerted by the many elements called "weather." Officials should know their factors of safety under normal circumstances, under average seasonal variations and under unusual conditions that may occur only once in 5, 10 or more years. However, to know is not sufficient. There should also be a plan of action to be followed during emergencies; a plan not formulated vaguely in the mind of one official, but a plan that has been discussed carefully with all members of the department and recorded in writing for reference and use.

The average water-works operator who has been properly trained will carry on satisfactorily under normal conditions and probably do reasonably well under somewhat unusual circumstances. The conditions preceding outbreaks of typhoid fever and other water-borne diseases, however, are commonly not of this type. Epidemics generally follow a break in the defense that is supposed to guard against them. They usually result from a combination of circumstances which in accordance with the laws of probability will occur but once in many years. Careful water-works officials, therefore, should always be on the alert for emergencies. Let us consider a common emergency and some of its possibilities. What would happen at a water-works plant if it should rain at a high rate of precipitation for, let us say, three consecutive hours? Would the dam hold? Would flooding of sewers or sewage-polluted streams affect the reservoir, clear well or tunnel shafts? Would water short-circuit through the reservoir and cut down the theoretical storage of forty days to forty hours, thus eliminating the factor of safety of storage? Would the supply become turbid, necessitating the use of chemical coagulants?

During the four years that the writer was in charge of the protection of Chicago's water supply, a control system for chlorination was developed which was based largely on a program of "watching the weather." Chicago's intakes in Lake Michigan are fixed. The sources of pollution of the lake are known. From a control standpoint, therefore, it became necessary to learn all we could about those factors which might carry pollution to the intakes. Our studies involved rates of rainfall and the effect of run-off into the lake, the time and probable duration of river reversals, the effect of dispersion, the rate of drift of pollution in the lake and the influence of prolonged winds and barometric pressures on the lake levels. Automatic recording rain gages at four places in the city made it possible to predict — even while the rain was falling — the probable effect the run-off would have on the direction of flow of the rivers. Flow vanes at key points in the river equipped with alarm lights and bells gave warning of reversals; recording gages showed river elevations, while automatic recording instruments for wind direction and velocity told the story of what might be expected in the way of drift of pollution toward the intakes, once it entered Lake Michigan. In other words, we studied our weak points and planned our campaign for control so that it might be put into operation while the emergency was brewing. Without such a system there would have been four or five occasions each year when we had no real factor of safety and would have operated on a wide margin of chance with the health of three million people as the stake.

In the writer's opinion any unusual change in weather conditions, such as excessive rainfall, high winds, prolonged drought, great heat or cold, warrants the application of emergency operation pending investigation. No harm can come from playing safe. In Chicago, orders for increase in the rate of chlorination for sterilizing water from intakes exposed to potential pollution were given whenever a southerly wind was predicted. During the periods of rainfall, the chlorine dosage was raised by at least one lb. per m.g. at all pumping stations as a safety factor against possible pollution of water in tunnels from sewers located near land shafts. Whenever emergency orders were issued, they were not withdrawn until the results of bacterial examination of special samples collected during the emergency had indicated it was safe to do so.

From an operating standpoint, it is essential that every water plant keep regular records of operation. But for protection, it is of the utmost importance that whatever special measures are taken during emergency periods be checked as to the results obtained. Special raw-water samples at the height of an emergency, supported by equivalent samples of the water delivered to consumers during the emergency and while the precautionary program is functioning, are of inestimable value. They not only tell the story of the extent of the emergency, but may serve as guides for the future, should similar circumstances develop. They, furthermore, afford protection in case of controversy originating in the emergency itself. At Chicago we

prepared for these emergency samples by storing special sterile bottles at all sampling points and having emergency sampling equipment on hand at the laboratory for immediate use.

It is obvious that the smaller water works cannot afford to have the expensive equipment considered necessary in large cities; but there is no reason why the officials of smaller water works cannot apply the fundamental precautions indicated as desirable through a keen study of weather conditions and their relation to the peculiar features at their respective plants. Make it a point to study the effect and influence of every period of unusual weather on the operation of the plant and the quality of the water delivered. Watch for the unusual with that unceasing instinct which makes the experienced Yankee sailor put into port with the first threat of a southeaster. The water-works official who is on the alert for the unusual rarely has to meet with serious emergencies. He instills into his men that element of watchfulness and carefulness which prepares them to meet calmly all emergencies. He develops them to a degree of efficiency and discipline which produces prompt and effective response to his directions when real emergencies arise.

Emergencies of any kind in supplying drinking water have a distinct public health aspect. For this reason it is wise for water-works officials to take into their fullest confidence the health officers who are charged with supervision over their supplies. The weak points in any water works should be known to the health officer. His advice should be sought in establishing a control program. He should be notified of emergencies as they develop or threaten. Experiences at one plant reported to him may later on save the day for some other water works. An outstanding example of this is the coöperative program developed through the Ohio River Interstate Stream Pollution Agreement for notification of water-works operators by the state departments of health of spills of phenol wastes on the Ohio River watershed.

In conclusion, let me say that this paper is a plea to water-works officials to "watch the weather," that they may know its relations to the weak features of their respective plants; that they may work out an effective plan of action when emergencies arise; and that they may work in full harmony and coöperation with the proper health authorities in producing for the consuming public at all times, clean, safe and wholesome water.

Discussion.

Warren J. Scott.* Mr. Gorman's paper is excellent in pointing out the dangers that constantly menace public water supplies, and I think it is all too true that few superintendents, particularly those who are in charge of our smaller water supplies, are prepared to cope with emergencies.

In Connecticut we have had some experience with this condition during

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the past few months, when our water supplies became very low due to the prolonged drought.

So far as watching the weather goes, some of the officials who are in charge of the supervision of our water supplies, unfortunately are prone to see supplies get low and then watch the weather, looking for rain to help them out of the emergency. This is the wrong time to watch. As Mr. Gorman has pointed out, it is essential that every superintendent, when his supply begins to get low, should try to develop some plan of action for getting water if the drought continues. Best of all, of course, is to plan enlargements before shortages threaten. Some officials are willing to take a chance with the health of the water takers in their respective communities and wait until the last minute, when they are forced to act quickly without proper preparation.

We had an example of this in a small community in Connecticut, where the supply was derived from a very small reservoir dependent on the immediate run-off of a small watershed. Here those in charge waited until the reservoir was very low and then started to pump water from a relatively highly polluted stream, without notifying the State Department of Health or the local health officials. We heard of this action on the next day and immediately installed emergency chlorination apparatus. Later the local officials installed a chlorinator of their own until rains relieved the situation temporarily. That is an example where a chance is taken from day to day in the hope that a shower will relieve the emergency. It is just as easy to make plans in advance for such emergencies.

So far as conditions of heavy run-off are concerned, I have found in my experience that a great many superintendents, in looking over the sanitary conditions of their watersheds, make inspections when dry-weather conditions prevail. Seeing a small gully that has no water in it and noticing a privy or cesspool overflowing at what seems to be a reasonable distance from the gully, they think there is no danger. If they made the inspection of the watershed when there was a heavy run-off, they would readily realize the great danger from material washing into the supply.

I think both points made by Mr. Gorman, as to watching over the water supply with reference to its safety at times of drought and at times of heavy run-off, are of very great importance and cannot be stressed too much.

TESTING LARGE METERS.

BY R. E. FERGUSON.*

[*Read September 18, 1929.*]

The following are four of the best-known methods of testing meters:

1. By discharging the water through the meter into a tank which rests on scales.
2. By discharging the water through the meter into a tank which has been previously calibrated in cubic feet or gallons.
3. By the use of the Freeman nozzle.
4. By testing the meter in the field with a previously calibrated meter.

As most water-works men are familiar with the first two methods, the author will confine himself to descriptions of the last two.

Use of the Freeman Nozzle. Meter testing by use of the Freeman nozzle is generally confined to laboratories of insurance companies, pump-manufacturing companies and universities. If one has an unlimited flow of water, the nozzle test possesses the following advantages over the tank and scale tests. The range of flow is easily controlled, the duration of the test is not confined to a few hundred cubic feet, and if the tests are conducted in a careful manner, they are very accurate.

Figure 1 shows an 8-in. meter placed in a nozzle-testing machine which is located in the shops of the Lowell Water Department, Lowell, Mass. This is a 6-in. machine. To test an 8-in. meter, the inlet end of the supply was provided with a 6 x 8-in. adapter and about 12 ft. of 8-in. straight pipe. To the outlet end of the meter was attached an 8 x 6-in. adapter, control valves and about 8 ft. of straight 6-in. pipe, with the piezometer and nozzle on the end. This straight piece of pipe ahead of the piezometer was sufficient to destroy all the eddies and currents induced by the change in pipe sizes. The pressure in the piezometer was regulated by three valves, 6, 2 and 1 in. in size. In running a test, the larger valve was opened until the pressure was within about ½ lb. per sq. in. of that desired; then the small valve was used for the finer adjustments. With this small valve, any slight fluctuations in pressure could also be controlled. During the test, the pressure was checked in two ways: (1) by a spring gage which was attached to the piezometer and (2) by a mercury column which was also attached to the piezometer, through the same connections as the spring gage. The spring gage was graduated to 0.1, and the mercury column to 0.2 lb. per sq. in. On this test 1, 2 and 4-in. nozzles were used. The rates varied from 75 to 2 880 g.p.m. The pressure at the nozzle was varied

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FIG. 1. — NOZZLE TESTING EQUIPMENT, LOWELL WATER DEPARTMENT.

from a minimum of 6 to a maximum of 29 lb. per sq. in. The pressure on the inlet side of the supply line was 70 lb. per sq. in.

On the inlet end of the supply pipe, an air-release valve was installed. The water was supplied through about 40 ft. of 6-in. pipe to the test machine, this pipe being a take-off from a 24-in. main. The water was discharged into the pump well and there was no waste of water.

Use of a Calibrated Meter. Figure 2 shows an installation of a 4-in.

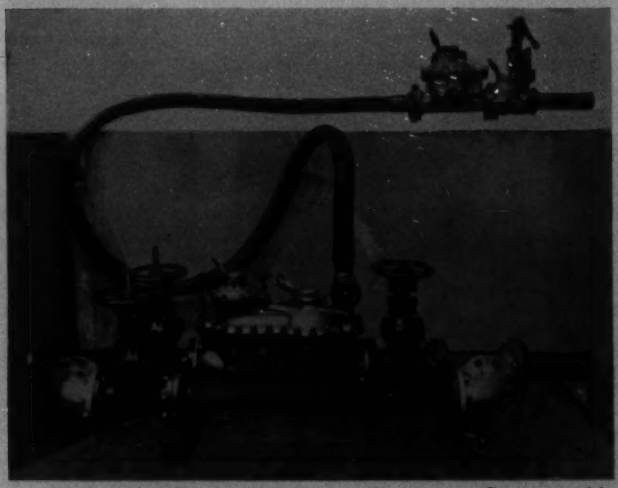

FIG. 2.— EQUIPMENT FOR TESTING METERS IN THE FIELD WITH A CALIBRATED METER.

compound meter with a 4-in. by-pass and the proper valves installed so that the meter-repair man can test and repair the meter without interference with the consumer's water supply.

In some cities, these by-passes are of the same size as the meter. That is to say, if there is a 4-in. supply line, the by-pass around the meter is also 4 in. This by-pass flow is controlled with a gate valve which is locked by means of a chain and padlock, the only key to which is held by the water department. In some cases, seals are used. In Fig. 2, the test meter is shown attached directly to the meter with a 2½-in. hose. In some cases, a test tee is installed in the line between the outlet end of the meter and the gate valve. The installation shown has a 2-in. gate valve attached to the meter below the hose connections, the advantage of this being that when making a test, the valve on the inlet side of the meter does not have to be shut to make test connections. If it is necessary to shut the valve to make test connections, the incrustation from the sides of the valve may be broken

and lodge in the meter. This would require opening the meter and cleaning it before conducting a test, a necessity which in the case of a disputed bill would make the test almost worthless.

Figure 2 also shows the type of meters which we have used a good many years for making this test,—a 3-in. velocity meter for the large flows, and a ¾-in. disc meter for the small flows. These two meters are connected to the meter to be tested with a 2½-in. high-pressure hose, the flows through the 3-in. meter being controlled by a 3-in. quick-closing valve, and the flows through the small meter being controlled by a ¾-in. angle valve on the side of the 3-in. meter to which is attached the ¾-in. meter. When using the small meter, the 3-in. gate is closed, and vice versa. The 3-in. valve is a quick-closing valve. This enables the tester to close the meter more accurately than by a screw-stem valve. The rate of flow is controlled by only partially opening the quick-opening valve. With a little experience, the tester can gage the flows very closely to the desired rates. Of course, he checks the flows with a stop-watch. In some cities, different-sized orifices are used to control the rate of flow. As the pressure varies in different localities, the rate of flow does likewise.

In some cities, where large meters are tested at least once a year, the engineer in charge runs what is called an up-and-down test. This is performed by opening and closing the controlling valve slowly during the test so that the flow will vary from the minimum to the maximum rate of the test meter. This almost invariably not only covers the average rate of consumption, but the small night flow and the peak load.

In testing large meters with this apparatus and with from 15 to 20 ft. of hose under 50 lb. per sq. in. pressure, one is able to test flows as large as 450 to 500 g.p.m., which in all ordinary cases is ample. For the low flows, for which the ¾- or 1-in. meter is used, one is able to test the minimum rate at which the meter to be tested is guaranteed.

There are two reasons for using a velocity meter. The loss of pressure is very low at high rates, and at the same time the velocity meter will pass sand and small particles of dirt without interfering with the registration. There is also a strainer on the bottom of the measuring chamber that will stop foreign matter which is large enough to retard registration. I am not inferring that most water departments have more or less sand in the water, but in running these tests, especially on flows larger than the average consumption, if there is any accumulation of sand or dirt in the pipes at all, it will be drawn through the test meter. This is not true of the smaller rates of flow through the ¾-in. disc meter.

In testing any type of compound meter, it has been our practice to test the smaller flow first, so that any error in the meter can be segregated. If on testing the by-pass meter, it is found to be in error, this error is corrected before running flows that are registered on both the main-line and by-pass meters.

We have no specified rates of flow at which we test meters in the field,

as we allow the superintendent to designate the test rate he wishes us to run, because in a good many cases, the superintendent has a very good idea of the average rate of consumption through the meter. Before making these tests, the test meter is tested in our Testing Department, and the test card is attached to the meter before it is shipped.

Before closing, I would like to say a few words on a subject which is very closely related to testing, *i.e.*, pits in which the meters are set. I have seen meters set in pits so small that the top of the pit had to be removed before one could hook up the test apparatus. I have seen a meter set with a 3-in. gas pipe crossing the top at right angles and clearing the meter by not over 6 in. In a number of cases, meters are set in pits so narrow that a man could not remove the meter bolts except with a socket wrench or a hammer and chisel. While this is unavoidable in a good many cases owing to other underground conditions, I believe we would find the pits larger, if the man in charge of building meter pits kept in mind the fact that the meter might eventually require repairs and that in all probability the work would be done in the pit. If the meter cannot be set without the cover being close to the top, the pit should be dug 18 in. or 2 ft. below the bottom of the meter, and should be drained if possible. This will not only help the repair man, but also will assist in keeping the registers cleaner.

RECONSTRUCTION OF THE WOODLAWN PUMPING STATION OF THE WESTERN NEW YORK WATER COMPANY AT BUFFALO IN CONNECTION WITH THE CONSTRUCTION OF A TWENTY MILLION GALLON FILTER PLANT.

BY H. F. HUY.*

[*Read September 19, 1929.*]

The Western New York Water Company supplies the suburban territory of the city of Buffalo including the shops and yards of the New York Central Railway in East Buffalo within the city limits. The territory supplied comprises a population estimated at 120 000 and is developing rapidly.

The distribution system of the water company comprises 300 miles of mains varying from 30 to 4 in. in diameter, the average being slightly in excess of 12 in. The water company also furnishes water to various villages and water districts at wholesale rates for distribution by the purchasers through approximately 250 miles of mains.

The water supply is obtained from Lake Erie, and the main pumping station and filter plant are located on the lake shore at Woodlawn, south of the city of Buffalo. The supply mains completely encircle the city and extend eastward for 18 miles to supply railroads and Erie County institutions. About 50 per cent. of the water has to be repumped by booster stations. The total pumping head is 540 ft., and water is supplied to the consumers at pressures varying from 50 to 120 lb. per sq. in., depending on the distance and elevation of the delivery point.

Intakes and Intake Pipes. The intake pipes consist of a 20- and a 30-in. pipe extending about one mile into Lake Erie to a submerged depth of 24 ft. The pipes are laid in a rock trench below the bed of the lake to prevent damage from shifting ice floes. Monolithic concrete cribs are placed at the intake end of the pipe lines and are bedded in the rock to prevent possible movement due to ice. Experience has shown them to be deep enough below the water surface to avoid ice troubles. The intake cribs have about 22 ft. of water over the screen which is on top of the structure. The screen area is such that the intake entrance velocity does not exceed $\frac{1}{2}$ ft. per sec. Any debris or other material that tends to clog the screens, including slush ice which forms in cold weather before the lake surface has become frozen, is removed by back flushing the screens with water from the intake well on shore. A head on the screens of about 10 ft. clears them in four or five 20-minute periods of flushing. Slush ice seldom causes trouble for more than 24 hours and occurs only at times when the ice is beginning to form on the lake surface. When necessary, the intakes are examined by a diver.

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In the winter the diving equipment is taken out on the ice, and the diver descends to the intakes through a hole cut in the ice. Both intakes are carefully located by ranges on the shore.

The first intake was 20 in. in diameter and was constructed in 1900. Its crib was not anchored sufficiently well to resist wave and ice action. As a result it shifted, and the intake entrance became plugged with shale and sand. A 30-in. intake was therefore installed in 1908 and supplied sufficient water until 1925. At that time more water was required, and repairs were made to the old intake. While the old crib was being replaced by a new monolithic concrete structure, it was discovered that a large amount of shale and sand had entered the 20-in. pipe, filling it almost completely for the first 100 ft. Further towards the shore a fine silt had been deposited in the pipe. The silt evidently settled from the turbid water entering the pipe, sedimentation taking place because of the very low velocity of flow caused by the small entrance area. This deposit decreased gradually in volume. About 400 ft. from the intake entrance it occupied about half the pipe, and there were indications that silt would be found for about 2 000 ft. towards the shore. To clear the pipe the first section, 400 ft. in length, was removed and cleaned. The remaining 2 000 ft. were cleared by forcing large cakes of ice through the pipe. The ice was introduced by a diver, and flow was induced by pumping from the shore well. This method of silt removal was successful. After the work was completed, tests of the friction losses showed that both intakes delivered quantities of water about 8 to 10 per cent. in excess of the amounts given by the Hazen and Williams formula for new pipe. This experience demonstrates that care should be exercised in designing intakes or pipe lines conveying turbid waters. A self-cleaning velocity should be provided to prevent sedimentation. Otherwise, deposition of silt will take place, and the pipe area will be restricted until a self-cleaning velocity is created. A velocity of 2 ft. per sec. may be considered adequate.

The intake pipes are laid on a grade rising towards the shore. At the suction well the pipe is only 8 ft. below lake level. Inside the well it drops vertically to a point 22 ft. below lake level. The whole pipe line is water sealed, and there has been no air trouble, although provision is made for removing any accumulation of air. At the summit of the intake pipe gages measure the friction loss through the line and allow the operators at the pumping plant to observe whether the intake crib screens are free from debris and slush ice.

Pumping Station and Filtration Plant. The pumping station and filter plant are located about 1 000 ft. from the lake shore. They are incorporated in a brick structure with foundations carried to rock about 10 ft. below the ground surface. The material lying above rock is peaty and boggy in character and is unstable and unsatisfactory even for light loads. The original pumping station was built in 1900 and contained triple expansion, direct-acting, duplex pumps and horizontal return tubular boilers.

As the lake levels fluctuate about 10 ft. under the influence of high winds, the main pump floor was placed 10 ft. above lake level. Thus it was necessary to operate the steam pumps with a suction lift of 28 ft. In 1908, when it became necessary to increase the capacity of the pumping plant, Niagara electric power was offered at the low rate of $16.00 per h.p. per annum for the night hours of 6 P.M. to 7 A.M. and $24.00 per h.p. per annum for the remaining hours of the day. The rate was based on a 5-minute peak load. Two 5-m.g.d. electric driven, centrifugal pumps were, therefore, installed and current was delivered at 12 000 volts and was stepped down by transformers to 440 volts. The steam plant was kept as a reserve but a 10-m.g. reservoir was constructed at a proper elevation to permit night pumping most of the time until 1914. This reservoir also provided a reserve during failure of electric power for short periods.

Water Supply. Until 1910 the lake water was considered satisfactory for domestic use, but following sporadic outbreaks of typhoid, hypochlorite of lime was added to the water. In 1913 liquid chlorine was first employed after the results obtained with the original liquid chlorine apparatus used by the water company at its Niagara Falls Plant installed in 1912 became available. The first liquid chlorine apparatus was used until 1923 when a new machine manufactured by Wallace and Tiernan was installed, because replacement parts for the old machine were no longer purchaseable. The present apparatus has recording scales to check uniformity of application. By the application of chlorine, water free from *B. coli* in 10 cc. samples and low in bacterial count was supplied to consumers. A residual chlorine content of 0.20 p.p.m. at the pumping station, as determined by the ortho-tolidin test, was maintained. The average gelatin count of the raw lake water is 1 200 per cc., but the count rises at times to 6 000 or 7 000 colonies per cc. in stormy weather.

While the water was bacterially safe, it was criticized at times because of its turbidity and the tastes occasioned when chlorophenol compounds were formed. Several steel plants and other manufactories discharge phenol wastes into Lake Erie and Buffalo Harbor. High winds from the west and southwest cause high turbidity and raise the water level at the easterly end of the lake, inducing a back wash or undertow which carries the phenol and other shore wastes out into the lake. It is not unusual to have the wind raise the lake level 8 ft. above normal at Buffalo. Since the Niagara River channel is not large enough to discharge the water, a heavy undertow is formed, and phenolic wastes reach the intakes of the water company. Combining with the chlorine, these wastes caused considerable complaint of bad tastes. Tastes and turbidity were observed mostly in the spring and fall of the year and only occasionally in the summer months. No trouble was experienced when the ice had formed on the lake. During about 8 months of the year the turbidity did not exceed 10 p.p.m., but during the remaining 4 months it varied anywhere from 10 to 200 p.p.m. with increased chlorophenol tastes. Intestinal sickness was occasionally reported and

was ascribed to drinking turbid water, although the water showed low bacterial counts with no *B. coli* recorded in 10 cc. samples. Algæ troubles occurred during about one month of the year, usually during April or May.

Plant Improvements. In order to eliminate complaints, the Water Company decided to build a filtration plant. This plant was constructed at the main pumping station. An additional high-service pump was installed, and as use of the filtration plant required additional electric power for the low-lift pumps, it was necessary to increase and revamp the transformer and switching arrangements to receive the power from the electric company.

The steam reserve was abandoned, because twenty years' experience had shown that reservoir storage was ample to carry the works over the longest period of interruption of electric power. The longest interruption of service recorded was 8 hours, shut downs generally lasting only a few minutes and seldom exceeding one or two hours. This left part of the original station free for the new filter plant. The filtration plant and electrical changes were so planned that to place them in service required only the opening and closing of a few valves. The sedimentation basin, filters and low-service pumps were all tested prior to placing them in use. Changes to the electric and switching board apparatus, additional transformer and bus bars were made with little or no interruption of service. This part of the improvements necessitated considerable change as the original plant was more or less obsolete after twenty years of service. The power is now supplied through three service lines and is furnished by the Niagara Company. The current is 3-phase, 25-cycle delivered at 12 000 volts and stepped down for motor use to 440 volts. The price is about $36 per h.p. per annum. The charge is fixed by the maximum demand of a 3-minute peak load plus the energy charge, with a slight charge for coal when power is furnished from steam plants.

Filtration Plant. The filtration plant comprises a low-lift pump-well, a building housing three 8-m.g.d. low-lift pumps with electric motors, a 3.5-m.g. sedimentation basin, 16 filter units superimposed on a 0.75-m.g. clear-water basin and a 0.2-m.g. elevated wash-water tank. The sedimentation basin and wash-water tank were designed large enough to permit duplication of the filtration units.

The boiler room of the original pumping station was demolished to provide space for the filters, and the steam pump room was utilized as a chemical house. Store rooms for supplies, heating plant, laboratory, lavatories and superintendent's office were so arranged as to allow adding a story above them for future needs of the water company.

Low-Lift Pump Station. The low-lift pump room was built over a new suction well constructed at the shore end of the intake adjacent to the main station. The suction well is elliptical in shape, 26 by 22 ft. in plan and 34 ft. deep with reinforced concrete walls 2 ft. thick. This well contains screens and two-deck floors below the main floor, the lower one for support-

ing the 8-m.g.d. De Laval centrifugal pumps, the upper one carrying the vertical shaft guide bearings and the exhausters for priming the pumps. The main floor is occupied by the motors and switchboard control. The pumping apparatus was installed so as to secure rigidity in operation. The thrust bearing of the double-suction pumps is on the top of the casing; there is no lower bearing. The pumps have a guaranteed efficiency of 84 per cent., and the guaranteed motor efficiency is 94 per cent. at full load. The apparatus passed the test, and the efficiency curve was quite flat between 75 and 115 per cent. load. In the low-lift pump station are installed valves controlling flow to the sedimentation basin and from the clear well to the high-service pump well. Gages are provided to show rates of pumping and elevation of water in the sedimentation basin, clear well and suction well and to indicate friction losses in the intake pipes. The latter tell the operator whether the intake screens are clear. The discharge from each low-lift pump is equipped with a Venturi tube with a manometer located on the main floor. All pumps are siamesed into a 24-in. main leading to the sedimentation basin and are cross-connected with other pipes so as to permit pumping water directly to the filters, the clear well and high-service suction well. Valves are installed which permit the high-service pumps to take water directly from the intake lines.

Sedimentation Basin. The sedimentation basin is 235 ft. long, 110 ft. wide, and 17 ft. 6 in. deep above the footings with a normal water depth of 16 ft. The structure rests on Raymond concrete columns 6 to 8 ft. long and 18 in. in diameter, driven to rock. This was necessary on account of the poor bearing value of the ground and the desirability for cleaning the basin without pumping. The basin is divided into two sections, the water entering on the far side and passing the length of the basin, returning back to a collector which carries it to the filters. The water level is maintained about 4 ft. above the flowline of the filters to allow for friction losses in pipes and possible variations in pumping loads or electric-power interruptions. The walls and floors resting on the corbelled columns to rock are constructed of reinforced concrete. The floor is dished to the centre where a blow-off or clean-out pipe is encased in concrete below the basin floor. This pipe leads to an open channel on the outside of the basin. High-pressure pipe lines with hose connections are attached to the side walls on the inside of the basin and permit cleaning the basin by flushing the settled material into the blow-off main. It is necessary to clean the basin twice a year. About 24 hours are needed to empty, clean and refill the basin. During the cleaning of the basin, water is pumped directly to the filters. The capacity of the basin is 3.5 m.g. and gives about 4 hours' detention when operated at a 20-m.g.d. rate. The loading on each pile column is 32 tons under the main floor and 26 tons under the walls. The piles are spaced on 7-ft. centres under the floor and on 3.5-ft. centres longitudinally under wall footings. Before building the basin, the columns were tested by loading a grillage weighing 140 tons on 4 columns. This is equivalent to 35 tons per column.

No settlement or crushing of columns was observed. The peaty and marshy character of the soil very often necessitated the removal of the top surface to a depth of about 12 in. and the refilling of the excavation with crushed slag. The reinforced concrete floor and footings were placed on top of this filling. Good work was thus secured and the muck was prevented from mixing with the concrete placed. Tests were made by loading the slag fill. These showed a settlement of ¾ in. with three times the weight of concrete floor and of ¼ to ½ in. when loaded with the actual weight of the floor. The settlement stress in placing the concrete was, therefore, negligible. Expansion joints were placed every 60 ft. in the side walls. Surplus excavation was placed on the outside of the walls to form a berme with a top width of 5 ft. and slopes of 1½ to 1. On the slopes were planted 10 000 periwinkle vines spaced 15 in. on centres to obviate the necessity of cutting grass. The inside of the basin was waterproofed with two coats of Inertol to within 6 ft. of the top of the walls. The balance of the walls and tops were waterproofed with Hydrocide waterproofing.

Filters. The filters consist of 16 units 17.5 by 20 ft. in plans. Their capacity is 16 m.g.d. when filtering at a rate of 125 m.g.a.d. Individual beds have been operated at a rate of 160 m.g.a.d. without material increase in washing and up to 190 m.g.a.d. with about 30 per cent. increase in washings. The filter boxes are constructed of reinforced concrete and rest on the walls and columns of the clear well. A brick superstructure covers about half the filters. The balance of the filters extends outside the building and is covered with a concrete roof. Manholes give access to the filters and permit removing sand if necessary. A pipe gallery separates the two rows of filter boxes. There are 8 units on each side, and the gallery is ample in size for maintenance and repair of apparatus.

The underdrain system consists of cast-iron manifolds with 2-in. cast-iron cement-lined laterals. The laterals are drilled for brass bushings with $\frac{5}{16}$-in. clear openings. These openings are staggered and point towards the floor of the filter. The manifolds are drilled on the top and have brass strainers of the umbrella type. The main collector from the manifolds passes under the filter floor to the rate controller in the pipe gallery. This controller can be changed in rate from the operating tables on the main floor.

The filtering medium consists of 18 in. of collector gravel comprising 6 in. of gravel 2½ to 1 in. in size and 12 in. of smaller graded gravel in four sizes varying from 1 to $\frac{1}{32}$ in. On top of the gravel there are 30 in. of Cape May sand. Both sand and gravel were tested with hydrochloric acid for solubility. The sand has an effective size of 0.5 to 0.6 mm. and a uniformity of coefficient of 1.35. Operation of the filters is regulated from operating tables on the main floor controlling hydraulic valves. The filters are cleaned by high-velocity washing at a rate of 7.5 m.g.d. per filter or 15 g.p.m. per sq. ft. of filter area. The rate is measured and indicated by a meter installed for that purpose. The filters, ordinarily, require washing

after a run of 36 to 48 hours, but when algæ troubles or high turbidity are encountered, they must be cleaned after 12 hours. The use of copper sulphate has extended the runs to 24 hours by killing the algæ.

The clear well holds 0.75 m.g. and is located under the filters. It has a reinforced floor and side walls. Columns 7 to 8 ft. on centres support the filter boxes and brick superstructure. The floor and side walls were under-drained so as to insure a water-tight structure and prevent trouble during construction from upward water pressures; the floor is six feet below the ground-water level and during lake storms would be subjected to fourteen feet of upward pressure by the lake water. Such storms actually occurred during construction. Upon completion of the basin the drainage outlets were closed, because the weight of the superstructure together with the selected design of floor and walls became sufficient to withstand uplift when the basin is empty. The inner surface of the clear-water basin was coated with Ironite waterproofing solution which is very satisfactory for walls damp with moisture or seepage.

Concrete and Reinforcement. The concrete used in this work consisted of one part of Portland cement, two parts of clean, washed, sharp sand and four parts of clean washed gravel, all obtained locally. The cement conformed to the specifications of the American Society for Testing Materials. The reinforcing steel used was of the deformed type and conformed to standard specifications of billet steel for reinforcing bars. All lappings in framing were at least 40 diameters, and bars in slabs and beams were continuous between supports.

The concrete was mixed at a central plant and delivered to the site in cars. It was then lifted by a crane or carried by buggies close to its point of use so as to maintain a good mixture and not separate the aggregates. During cold weather, the materials were heated and protected from freezing by canvas covers and steam pipes. All forms were cleaned by washing them down with a hose or blowing them out with steam prior to placing the concrete. Exposed concrete surfaces were rubbed smooth with carborundum brick.

Filter Effluent. The effluent from the clear-water basin is conducted to the main pump well through a 24-in. main. The water level in this well is automatically held at the desired level. The well is the original structure that received the lake water prior to construction of the filter plant and is situated under the high-service pumps. The floor of the high-service pump room is 2 ft. above lake level and 10 ft. below the flowline of the clear-water basin. The water level in the well is usually kept about 5 ft. below the pump floor. The water is pumped to the consumers through four 5- to 6-m.g.d. electric driven, centrifugal pumps. The last pump was installed in 1928, and has a delivery capacity of 6 m.g.d. against a total head of 270 ft. with a pump efficiency of 84 and a motor efficiency of 94 per cent.

Chemicals. Sulphate of alumina in small lump size is used as a coagulant and is delivered in solution to the low-lift pump well. The solution

box is constructed of concrete and possesses a wooden hopper and slotted basket submerged to varying depths, depending on the rate of feed desired. The water required enters the bottom of the box, and the water level is controlled by an adjustable overflow. The rate of dissolving the chemical is directly proportional to the depth of submergence of the basket. The basket itself is stationary, and depth of submergence is changed by raising or lowering the overflow. Temperature changes in the water vary the rate at which alum is taken into solution, but not sufficiently to cause inconvenience in determining the proper depth of submergence for a given quantity of sulphate of alumina to be dissolved. The same apparatus is used for introducing copper sulphate when algæ troubles occur or for adding permanganate of potash for the elimination of chlorophenol tastes. When potassium permanganate is used, the chemical is placed in a fine wire-mesh basket inside the slotted hopper so as to retain the crystals which are very small.

The average amount of alum used is 70 lb. per m.g., and the floc is plainly visible in the sedimentation basin and on the filters. The alkalinity of the raw water varies from 85 to 95 p.p.m.

In combating algæ a solution of copper sulphate may be introduced into the low-lift pump well in a manner similar to that employed for adding alum. Filter washes are reduced 50 per cent. by this practice.

Liquid chlorine is added before and after filtration, 70 per cent. of the disinfectant used being introduced into the raw-water and the balance into the effluent from the filters at the high-service pumps. Usually a total of 2½ lb. per m.g. is used. When the water is turbid, however, the quantity required has been as high as 7 lb. per m.g. Permanganate of potash is introduced at a rate 0.2 to 0.5 lb. per m.g. into the raw water after application of liquid chlorine and eliminates chlorophenol tastes. The filter plant was constructed during the winter of 1927–1928, and filtered water was delivered to the consumers in December, 1928.

SOME USES OF AËRATION IN WATER PURIFICATION.

BY MALCOLM PIRNIE.*

[*Read September 19, 1929.*]

Many millions of dollars are needlessly lost annually in depreciation of water-works distribution systems and destruction of plumbing due to corrosive water supplies. The loss is greater in soft-water areas, such as New England, than in territories where hard waters predominate. No such difference need exist, however, in the light of what is known about the control of the corrosive activities of different waters. All waters fit for public water supply can be made equally non-active or non-corrosive at annual costs for treatment that are insignificant when compared with the saving in investment in distribution systems and plumbing.

Tillman's table† has made readily available the simple requirements for non-active waters. It is obvious from this table that to be non-active waters having bicarbonate alkalinities of less than 100 p.p.m. must not contain more than 2 p.p.m. of free CO_2 resulting in a pH between 8.1 and 8.3. Hence CO_2 is the chief offender in a clear filter effluent which is alkaline. Carbon dioxide is a dissolved gas found in clear waters from springs, wells, slow sand and rapid sand filters. It can be expelled by fine-spray aëration from clean waters down to a residual of from 2 to 4 p.p.m. The residual can be neutralized by adding hydrated lime at a rate of from 0.1 to 0.5 grains per gallon, resulting in a pH of 8 or over. Equivalent doses of caustic soda may be substituted for the lime whenever the addition of lime is undesirable. Such treatment may be provided at moderate cost compared with the resulting savings to all consumers of water.

Experiments on the effects of fine-spray aëration as a part of the purification process in treating various waters were begun by the author after the war. These experiments resulted in the adoption of fine-spray aëration both as a primary treatment and for expulsion of CO_2 from the filtered water at West Palm Beach, Fla., Albany, N. Y., and Providence, R. I. Fountain aëration of the settled water was installed at Watertown, N. Y. The waters treated by these plants are moderately to very soft and moderately to highly colored. Fine-spray aëration for the very turbid, soft Dan River water at Danville, Va., was provided for the water immediately after receiving the alum dose and has demonstrated its effectiveness during the last five years in producing satisfactory coagulation with much less alum and soda than was formerly required. Recent tests for a paper-mill supply from the acid waters of the upper Potomac River have shown that immediate

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†"Significance of Hydrogen-Ion Concentration in Drinking Water and Particularly for the Business of Water Supply," by A. Massink and J. A. Heymann, translated into English by Frank Hannan. *Jour. A. W. W. A.*, vol. viii, p. 240.

fine-spray aëration after dosing with soda ash produces an excellent quick-settling floc and a pH in the water equal to that produced by twice as much soda which, without aëration, yields a poor and finely-divided floc. In view of these tests and the fact that flood stages in the river carry turbidity similar to that in the Dan River, a fine-spray aërator is being designed for the dosed water before it enters the coagulation basins. The filter effluent will not be aërated, but the residual CO_2 will be completely neutralized with caustic soda.

In the filter plants just mentioned, aëration has proved to be invaluable as an aid to coagulation, as a means of reducing the corrosiveness of the water and in eliminating or greatly reducing tastes and odors. Plausible reasons for the part played by fine-spray aëration in the purification of these waters were outlined by the speaker in 1923 in a paper before the Indiana Sanitary and Water Supply Association, entitled "The Function of Aëration in Water Purification." These still seem plausible but space does not permit listing them here. Operating results of some of the filters are possibly of greater interest and are given below. The results, with exception of the pH, are expressed in parts per million.

West Palm Beach, Fla.

Average results of operation during February, 1929.

Raw water is dosed with an average of 3.32 grains per gallon of alum; pumped to aërator; falls into coagulating basins; passes through filters; effluent controlled by aëration in fine-spray nozzles and variable nozzle; water from effluent aërator treated with 0.14 grain per gallon of lime.

	Color.	Alkalinity.	CO_2.	pH.
Raw Water	107	25	1.5	7.3
Alum-treated Water	...	...	28.0*	5.5*
Water on Top of Filters	24	3.7	5.5	6.3
Aërator Effluent	15	6.0	3.3	6.7
Water in Clear Well after Liming	14	7.4	2.4	6.9

*Result of one test; not part of routine tests.

Harder well water is used for washing filters and causes increase in alkalinity in the effluent aërator. About three times as much lime should have been added to produce pH near 8.

Providence, R. I.

Average results of operation during January, 1929.

Rawwater is aërated; dosed with 0.54 grain per gallon of alum; passes through a mixer into open basins holding it about six days. Settled water passes through filters; filter effluent controlled by aëration similar to West

Palm Beach; water from effluent aërator treated with 0.18 grain per gallon of lime.

	Color.	Total Hardness.	Alkalinity.	CO_2.	pH.
Raw Water	35	5	4.2	1.7	6.0
Effluent from First Aërator	...	6	...	1.6	6.1
Alum-treated Water	...	...	...	5.3	5.9
Settled Water	...	...	...	3.8	6.1
Filtered Water	7	...	1.2	3.6	6.1
Effluent from Second Aërator	...	...	...	2.7	6.4
Effluent after Liming	11	10	4.5	0.2	7.7

In April, May and June, 1929, a pH average of 8.0 to 8.1 was obtained with 0.15 to 0.17 grain per gallon of lime.

Watertown, N. Y.

Test of operation, November 6, 1922.

Raw water dosed with 3.3 grains per gallon of alum as it enters an 8-day river basin through a mixer. Settled water aërated in a fountain and filtered.

	Paper Filtered Color.	Alkalinity.	CO_2.	pH.
Raw Water	90	32	3	6.9
Alum-treated Water	17	13	23	5.9
Water half way through River Basin	6	11	7	6.4
Outlet from River Basin	5	11	6	6.5
Filter Effluent	3	12	2	6.8

This water needed about 0.15 grain per gallon of lime to raise its pH close to 8.

Danville, Va.

Experiment, February 12, 1923.

Raw water dosed with 0.8 grain per gallon of soda ash followed by 2.0 grains per gallon of alum. Dosed water was mixed thoroughly and half of it immediately aërated. Both portions were then allowed to stand a few minutes.

	Turbidity.	Alkalinity.	CO_2.	pH.
Raw Water	180	16.5	2	7.4
Treated Water Not Aërated	No Floc	13.5	7	6.6
Treated Water Aërated	Excellent Floc	14.0	2	7.2
Water Filtered through Cotton	0	14.0	2	7.2

Test of plant operation August 28, 1929.

Raw water first dosed with 1.25 grains per gallon of alum and aërated through fine-spray aërator. Effluent from the aërator filtered and tested.

	Turbidity.	Alkalinity.	CO_2.	pH.
Raw water	500	22	...	7.1
Treated Water Aërated and Filtered...	0	10	4.5	6.5

Caustic soda is to be applied to the effluent to produce a pH close to 8. Less than a grain per gallon will usually be required.

AUTOMATIC CHLORINATION AT CONCORD, N. H.

BY PERCY R. SANDERS.*

[*Read September 18, 1929.*]

Concord's water supply is obtained from Penacook Lake located three miles north of the city. The lake has a surface of 368 acres and a catchment area of 3.77 sq. miles. The shores are rocky or of gravel, and the color of the water is very low. The lake is fed almost entirely by springs. The slopes are fairly steep and are only sparsely settled; the permanent population on the watershed is about 75 persons, and the summer population is now practically eliminated. There is some farming on the catchment area, and boating and fishing are allowed on certain portions of the lake. All boating is done under license issued by the water-works office so that a check can be kept on boat owners. Picnic parties and travellers are often seen along the shore and on the watershed. The city owns 98 per cent. of the shore line. At the upper end of the lake, there are two boathouses belonging to St. Paul's School whose crews practise and race on the lake during the spring season; the school's boats are licensed similar to all others.

The city's intake extends 2 200 ft. into the lake. The water passes through a brick conduit along the lake bottom and enters the gatehouse through two sets of screens. Thence it flows to the city through a 20-in. cast-iron main and an 18-in. cement-lined main. A portion of Concord is hilly and cannot be supplied by gravity. About two miles toward the city, therefore, a pumping station takes suction from these mains and pumps water to a 2-m.g. reservoir.

The city's consumption of water varies approximately from 2.6 to 3.4 m.g.d. The pumps are started every night at 5 o'clock and pump at a rate of 3.8 m.g.d. for seven or eight hours according to the demand. The rate of draft drops as low as 0.5 m.g.d. from the time that pumping is stopped about midnight until 5 or 6 o'clock in the morning when it gradually rises until it reaches 2.5 m.g.d., the maximum rate of use by that portion of the city which is supplied by gravity. When the pump is started the rate of flow is further increased to approximately 6.25 m.g.d., naturally decreasing during the evening. All the water is measured at the gatehouse by a 20 by 9-in. float-operated Venturi meter. Thus these wide variations of flow during the 24 hours are accurately determined.

Since the water supply is taken from a surface source and, therefore, liable to contamination, the water board was advised by Messrs. Metcalf and Eddy, the New Hampshire State Board of Health concurring, to chlorinate the water. The water board voted to carry out these recommendations and Metcalf and Eddy were authorized to submit a plan for

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the installation of a chlorinating plant. The good sanitary record of the water, as shown by analyses, during the fifty-seven years that the supply had been in use, indicated that a minimum dose of chlorine would be required. This has proved to be true in practice.

With a flow varying from 0.5 to 6.25 m.g.d. the use of a manually operated chlorinator was out of the question. An automatic machine was, therefore, recommended and installed in the fall of 1928. The machine was furnished by Wallace & Tiernan and is their Type ASVM Automatic Control Vacuum Feed Chlorinator. An ortho-tolidin testing outfit was purchased at the same time.

Before the type of machine was decided upon, tests were made of the range in the differential heads on the Venturi meter. It was found that they varied from 0.4 to 5.82 ft. or in a ratio of 1 to 14.5. Wallace & Tiernan's pressure type chlorinator has a range ratio of 1 to 5, *i.e.*, the maximum rate of application is five times the minimum; the vacuum type has a ratio of 1 to 4. Since the flow varies in proportion to the square root of the Venturi meter differential heads, the vacuum type adequatedly covered the range of flows in the system. Local difficulties connected with the installation of the pressure type chlorinator decided the selection of the vacuum type of machine.

The chlorination equipment was placed in the gatehouse, a small room having been built for it, and the water is chlorinated after passing the screens. Four chlorine-metering tubes were furnished with the machine. These permit the chlorine to be applied at rates of 30, 24, 17, and 15 lb. per day. At first the 17-lb. tube was employed, giving a dose of 2.8 lb. per m.g.; later a change was made to the 15-lb. tube giving a dose of 2.5 lb. per m.g. or 0.33 p.p.m.

The pressure on the water line which carries the chlorine solution into the water is 33 lb. per sq. in., and the amount of water used to operate the machine is 6 000 gal. per day or approximately 2 200 gal. per m.g. chlorinated.

The ortho-tolidin test is made on samples taken a short distance below the Venturi meter to ascertain if any residual or free chlorine is present in the water. While a residual is always obtained at this point in the system, none is observed at the pumping station. This shows that all chlorine has been absorbed in the intervening time.

The desired chlorine dosage is kept constant for the varying flows because the chlorinator is operated by the differential in the throat and inlet pressures of the Venturi meter located 66 ft. from the machine. The differential pressure is transmitted 22 ft. to a differential converter which changes the differential pressure to a vacuum operating the chlorinator. The converter is situated 44 ft. from the chlorinator horizontally and 22 ft. below it.

Operation of the machine was put under the care of an employee on our permanent staff who was thoroughly drilled for his task by Mr. Hart of

Wallace & Tiernan. Like any other automatic device, the machine requires attention so that everything may work as it should. The plant is visited four days a week to weigh the chlorine and check operation.

The main troubles experienced have been the sticking of the chlorine-reducing valve and wear of the gaskets in the chlorine injector throat. In the winter months we have a little difficulty in keeping the chlorine equipment and room at an even temperature. Heat is supplied by an ordinary oil heater connected by a small pipe to a 10-gal. oil reservoir, the flow line of which is at same level as the burner. In cold weather chlorine hydrate is formed and sometimes affects the chlorine-reducing valve. The vacuum line leading from the differential converter to the machine has to be drained from time to time, as condensation will otherwise collect and interfere with chlorination. These are minor difficulties that are easily remedied.

A small bottle of ammonia is kept in the gatehouse to detect leaks in the equipment, and a gas mask is hung just inside the main door for emergency use in case of bad leaks. This mask has been used on occasion.

Liquid chlorine is purchased from the M. Brown Company of Berlin, N. H., who manufacture and use great quantities of chlorine in connection with their bleaching processes.

The chlorinator was operated for several months before the fact of its use was made public. During this time no complaints were received of unusual tastes or odors in the water. As soon as the consumers learned that the water was being chlorinated, however, discoloration was suddenly noted on glass ware; one or two persons developed boils which they thought could be attributed to the chlorine; and many people thought that the water had tasted queer for some time but had not known what the trouble was; we even had communications by mail assuring us that the change in the water had been detected several weeks before.

Complaints soon ceased and the water is being chlorinated regularly and continually; no one notices the difference in the ordinary course of events; occasionally a consumer returns from a vacation and inquires if the water drawn from pipes unused for a month or two tastes and smells queer because of chlorination. Such occasional complaints seem to be the only reminder of the change. There has been no marked improvement in the health of our citizens, but we rest secure in the thought that we are doing our best to give our community a safe water.

ENFORCEMENT WITH OTHER BEVERAGES.

BY J. FREDERICK JACKSON.*

[*Read September 20, 1929.*]

Controversies have raged and are still raging over the enforcement of the Volstead act. A paper on law enforcement, from a professional viewpoint, might not at first thought seem to have a place in a water-works journal; nevertheless there are many comparable points in enforcement of laws controlling liquor and those relating to other beverages. In the particular phase of control with which this paper will deal the comparisons in many ways are particularly striking. There is, for example, the question of Federal versus State control of liquor and State versus local control of drinking water; there is the menace to health from poisoned liquor and also from polluted water supplies; there is infringement of personal rights in both cases; and not least there are the enormous cost and practical impossibility of enforcing many statutes relating to control of use of both beverages.

Sale or consumption of liquor in some form is taking place every day in practically every hotel, club and home throughout the country. Law enforcement agencies are totally inadequate to combat it, and when arrests are made and convictions are secured they have no appreciable deterrent effect. In the phase of control of water supplies which this paper discusses, *i.e.*, "bathing in reservoirs," the law is being broken every day throughout the bathing season, generally without the knowledge of the supervising authorities but still quite often with their tacit acquiescence.

The complexity of this problem is very well illustrated by some of the experiences of Connecticut. For many years there has been in force in the State of Connecticut a statute (Rev. 1918–Sec. 2544) which reads "Every person who shall bathe in any reservoir from which the inhabitants of any town, city or borough are supplied with water, or in any lake, pond or stream tributary to such reservoir, or who shall cast any filthy or impure substance into such reservoir, or any of its tributaries, or commit any nuisance in or about it or them, shall be fined not more than one hundred dollars or imprisoned not more than six months or both. Prosecutions under this section may be had in the town in which said city or borough is."

Cases where local authorities and state officials were called on to act under this statute have been few, and it will be noticed that no particular state or local agency or officer is specifically charged with the enforcement of the statute.

In Connecticut, as in other states, the increase in bathing due to activities of health authorities, Red Cross life-saving courses and wider instruction in swimming both in indoor and outdoor pools, and the growth

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of camping facilities provided by social and health agencies, have caused practically every natural lake of appreciable size, as well as many artificial ones and small streams feeding them to be used extensively for bathing, boating and fishing. Where such bodies of water are not part of a public water supply very little trouble results. Though in some camps which take their water supply from lakes in which bathing is permitted, careful supervision must be exercised. Then, too, some water companies in a community spirit have provided picnic facilities on the banks of their reservoirs for local people. Generally, however, this privilege has been so abused by parties coming from a distance and possessing no local connections that it has had to be discontinued. With the rapid increase in camps and other recreational resorts and with the improved facilities for travel by automobile it was inevitable that violations of the statute should have become so flagrant in certain instances that they could not be ignored.

The Lake Wamgumbaug Case. The first real test of the law in Connecticut came when complaints began to be made of heavy bathing in Lake Wamgumbaug, the source of water supply for the South Coventry Water Supply Company, supplying about 600 people in the town of South Coventry.

There is a considerable cottage colony on this lake. The first step taken to prevent bathing was to post the entire lake with signs warning all that it was unlawful to bathe in the waters of the lake. These signs were promptly torn down, and a mass meeting of the cottagers was called to protest the action of the State Department of Health in posting the lake. This meeting was finally convinced that the department was only carrying out its legal duty, and the indignation and revolt subsided, so far, at least, as to permit the replaced posters to remain undisturbed. But, according to reports of inspectors, bathing in the lake still continued. It was then decided to enlist the services of the State Police who assigned a man to patrol the lake. The trooper had instructions to arrest anyone found bathing in the lake. After several days this officer was able to catch, in the act of bathing, an individual whom he promptly arrested and hailed before the local justice of the peace. The justice, having heard the evidence, however, discharged the individual in question. (Gossip had it that the culprit and the justice were related in some way.)

The next step in the controversy was to bring the case before another court, and the county health officer was requested to prosecute. Due to sickness and prior engagements of the county health officer, the case did not come up, and bathing still continued.

There were many interesting side lights in the case, but this paper will confine itself to really important issues. Finally it was decided to enlist the assistance of the attorney general. The usual postponement and delays due to engagements of counsel elsewhere ensued, and the case dragged along until the bathing season was almost over. The water company in the meantime had been rather reluctant to push the prosecution. Many of the cot-

tagers were intimate friends of the water officials, and again they were not entirely convinced that the bathing constituted a serious menace to the public health.

Now there is in Connecticut another statute of long standing (Rev. 19–Sec. 2539) which states "No cemetery or place of sepulture shall be located or established within one-half mile of any reservoir from which the inhabitants of a town, city or borough are supplied with water, nor shall such reservoir be located or established within one-half mile of a cemetery or place of sepulture unless the superior court of the county wherein such cemetery or place of sepulture or reservoir is located shall, upon application and notice, find that such cemetery or place of sepulture or such reservoir so proposed to be located is of public convenience and necessity and will not be detrimental to the public health." In the preparation of the case it developed that there was a cemetery on the watershed of Lake Wamgumbaug within the statutory limit; furthermore, that the water company had never made application to the Superior Court to have this cemetery declared not to be detrimental to the public health. Therefore the attorney general ruled that the water company had no rights in the lake until the courts had decided on the cemetery location. The company having no rights in the lake, it was not a reservoir; therefore bathing in it was not unlawful.

The Roseland Lake Case. A second case deals with Roseland Lake, a reservoir of the city of Putnam, which had been used as a summer resort, boating and bathing being practically unrestricted. This place was also posted. The action brought forth vehement protests on the part of owners and concessionaries. No arrests were made at this place, and with the close of the summer season agitation subsided.

The Pine River Case. As previously stated, practically all available camp sites on natural lakes and desirable streams have been taken up by social and health agencies during the last few years. The real estate development companies were quick to realize the possibilities of camp site developments on lakes and rivers with bathing, boating and fishing privileges, and several of these companies bought large tracts bordering on small lakes or streams. These were cut up into small lots, and an intensive advertising and selling campaign was started. One such development by the Harvey Realty Company of New Haven was on the upper reaches of the Pine or Muddy River. About three or four miles below was a pumping station of the city of Wallingford. On the property of the realty company was a small pond which had been formed by throwing a dam across the river. This pond had been used for bathing for as long as the oldest resident could recall. The realty company repaired the dam, widened and deepened the pond, placed boats on it and widely advertised bathing and boating privileges. One particular advertisement was of a swimming carnival to be held on a Saturday and Sunday. There is a question whether the case would have caused the agitation it did, had this advertisement not been so

widely broadcast. The borough officials and the superintendent of the water works immediately notified the realty company to stop the public bathing and posted warning signs in the vicinity of the property. The president of the realty company protested and stated that he had taken this matter up before purchasing the property and had no intimation that there would be any objection from the water department to bathing.

Both sides appealed to the State Department of Health who had a survey made, as a result of which it decided that Statute 2544 applied and bathing in the pond and stream was unlawful. The department, too, posted warning signs. Several unfruitful conferences were held. No arrests were made, however, as the warning signs apparently accomplished their purpose.

The realty company claimed that as a result of the agitation sales of lots practically ceased and applied for a temporary injunction. Later it sought to have the injunction made permanent and brought suit for damages against the borough, the superintendent of the water department and the state commissioner of health. The borough in turn applied for a permanent injunction restraining the realty company from using the pond and river for bathing. The case was tried by a judge of the Superior Court, the trial lasting about a week. The plaintiff company claimed and sought to prove that the only definition of pollution was to be found in a statute creating a State Water Commission which said "The term pollution shall mean the contaminating or rendering unclean or impure of any water by reason of any sewage, waste or other material which shall be discharged or deposited by any public or private sewer or otherwise so as to directly or indirectly, immediately or ultimately mingle or come in contact with any water which may thereby tend to render or in fact render such water unclean or impure." Therefore, the plaintiff held that the act of bathing was not a pollution under the law. Witnesses for the plaintiff testified that the effect on health of bathing in a pond 3½ miles above the pump house, considering the methods provided for treating the water, was practically negligible. Testimony was also presented that the stream had been and was being used for bathing and watering cattle.

The defendant borough put members of the State Department of Health on the witness stand to show that a typhoid carrier was known to reside in the vicinity of the pond and that bathing was a menace to the public health. Other evidence tending to establish damages was introduced by the plaintiff and rebutted by the defendant. On the third day of the trial an unusual incident occurred. The judge interrupted proceedings to say that though he realized that it was unusual for the court to express any opinion until the case had been finished he felt that he ought to state in all fairness that irrespective of evidence he personally was unalterably opposed to bathing in a public water supply and felt it his duty to protect so far as he might the health of women and children. After this public declaration, the court called the attorneys into conference but no

agreement resulting the case proceeded. After the arguments, briefs were submitted by both sides. The court found for the defendants. In view of the importance of the case the language of the finding is interesting.

"The plaintiff bought a piece of cheap wild land on the outskirts of Wallingford and proceeded to lay it out into building lots and streets, and to advertise the sale of lots in a grossly exaggerated and misleading manner. There was a small mud hole on the premises, which the plaintiff cleaned and improved and made into a small pond. It is alleged 'that purchasers assumed that the pond would be and could be used for bathing and other lawful purposes.' Bathing was extensively featured in the advertisements. A large number of lots were sold, none of them on the pond, and the deeds do not give any bathing privileges. The advertisements invited church and fraternal societies to come in unlimited number for picnic purposes, and to bathe. The stream of which this little pond is a part runs into a reservoir and pumping station, and its water is used for public drinking purposes in Wallingford and is a part of the borough water supply. This fact was well known to the plaintiff. Bathing at this point would be a positive and serious menace to the public health.

"The gist of the complaint is that the water company unlawfully and without just cause interfered with the plaintiff's rights in that they publicly announced that bathing in this pond would be prohibited by them. The complaint presents no problems that are especially difficult of solution. If it is no action for slander on title, the plaintiff has failed to prove many necessary elements. If the complaint means something else, it does not say so. The two acts complained of are (1) That the State through its Commissioner of Health posted notices prohibiting bathing. This went out on demurrer, in so far as damages are concerned (it is to be observed that the posting of similar notices by the borough could cause no additional damage or injury). (2) That the borough officials posted similar notices. The fact is that they posted notices warning people that bathing there was unlawful. It was. And it was their legal duty to give such warning.

"Did they then unlawfully interfere with the plaintiff's reasonable use of its land? If this broad question is raised by the complaint, although inartificially stated, then it appears that:

"(*a*) None of the actual or prospective lot owners are riparian proprietors. They are not bounded on the pond. Neither their contracts nor their deeds mention or give any bathing privileges.

"(*b*) The plaintiff does not claim that its own right to bathe has been infringed.

"(*c*) Riparian rights include only, at most, a reasonable right to bathe. It is probable that this right is limited and restricted to a personal and family and limited guest right. The plaintiff proposes to bathe the public in unlimited numbers and to give them the right provided only by the riparian owner and his family. This does not constitute a reasonable use.

"(*d*) The plaintiff's rights cannot be taken without just compensation. The thing he seeks to protect is an unreasonable use of the water for bathing. He has no such right, and is deprived of nothing for which he can be compensated.

"(*e*) This was a place in which bathing is expressly prohibited by statute.

"(*f*) It was the duty of these officials to warn everybody that this was part of the public water supply and that bathing was prohibited by a penal statute.

"(*g*) The plaintiff cannot base a claim for damages on the intended violation of a penal statute, or upon acts constituting a direct and positive and serious menace to the public health, when these acts are in turn based on the unreasonable use of such waters,— a use which even the common law prohibits.

"The temporary injunction is dissolved and judgement on the complaint is for the defendants.

"The defendant has filed a counter-claim asking for a permanent injunction. The acts which it seeks to enjoin are so clearly illegal, and such adequate and easy enforcement is provided by the statute, that it would seem highly improper for this court to issue an injunction and make itself a police court for the enforcement of an ordinary criminal statute. There are specific penal statutes prohibiting all the acts complained of. If it develops that these do not adequately protect the public health, this court would at any time, including its vacation, instantly issue an injunction.

"Judgement is for the Plaintiff on the counter-claim."

The language of the court leaves no doubt of the prohibition of bathing in reservoirs and tributaries of water supplies where specific violations of the law are brought to its attention. But so far as stopping the practice by individuals or in isolated places, it leaves the whole matter just where it was. The court was not required to pass on practicability of enforcing the law nor on the relative danger from bathing in mass or individually. Neither did it choose to pass on effect of distance above intake at which bathing took place. Apparently in the eyes of the court under the statute there was just as great danger to public health whether the bathing was directly over the intake or thirty miles above it.

Fortunately no water supplies in Connecticut are from streams into which sewage is discharged by bordering communities. But if conditions were similiar to those in other states where large cities take their supplies from streams into which other communities on the river above discharge untreated or treated sewage and purify the water before delivering it to the consumers, would this have any effect on the ruling of the court and would such a statute be permitted to remain in force?

Small as Connecticut is in area compared to some of the larger states, violations are taking place every day during the bathing season unknown to state and water-company officials. To detect and prosecute violations in some of the larger states would require such an increase in the personnel of law enforcement agencies as to make it an absurdity.

The plaintiff realty company has appealed the case to the Superior Court, and this body's decision will be awaited with great interest. Whatever the court decides, the policy must be questioned of retaining a statute so broad that it defeats the purpose for which it was passed but does give a certain measure of protection; or repealing it and substituting one in which

limits of danger are defined and enforcement of which might be at least fifty per cent. efficient.

Perhaps the analogy between the enforcement of the two beverages has not been as clearly defined as the title of the paper would lead one to expect. But if discussion is stimulated which will help to correct an absurd situation, some progress will have been made.

Discussion.

Warren J. Scott.* Inasmuch as all the references to bathing in public water supplies cited in this paper are to conditions in Connecticut, it perhaps behooves me to offer a few comments. I will not attempt to draw further parallels between enforcement of the Volstead act and bathing laws, except to point out that the writer has raised the question as to the rights of the individual. Is the primary right that of drinking uncontaminated water or that of polluting the water by bathing in it? Certainly no one can deny that bathing pollutes water. Consider the percentage of typhoid patients with typhoid bacilli in their urine and the number of persons who urinate while bathing.

The author of the paper has pointed out practically all the serious controversies which have occurred in Connecticut regarding bathing in public water supplies. On the other hand, no mention is made of the vast number of Connecticut supplies where the law has been unquestionably obeyed. Where the State Department of Health has received information concerning pollution of water supplies by bathing, action has been taken to stop it. It is true, of course, that a very small amount of bathing many miles upstream on a supply with a large amount of storage and treatment is not nearly so serious as a large amount of bathing on a small stream without much protection.

It is also true that there is an increasing demand for the utilization of the recreational facilities on the drainage areas of our public water supplies. New England perhaps has fought this tendency more than other parts of the country because New England's water supplies have been dependent for their protection mostly on clean watersheds and storage. New England's typhoid record has been excellent. It has been lower than that of other sections of the country. In 1928, the typhoid death rate in Connecticut was only 0.6 per 100 000. As stated by E. Sherman Chase in a paper before the American Public Health Association, this low New England typhoid record "does not warrant the conclusion that New England cities should rest on their laurels, but it does show that New England methods of water supply protection, irrespective of opportunities for improvement therein, have been as successful, measured by the typhoid death rates, as those of other states."

*Director, Division of Sanitary Engineering, Connecticut State Department of Health, Hartford, Conn.

It is intimated in this paper that bathing laws such as the Connecticut law might be modified, with the idea that if the law were less stringent, it might be better enforced. The difficulty with such a proposal is to decide where to draw the line. It is true that sometimes too stringent regulations swing the pendulum of public sentiment too far toward lax standards, as happened in the State of New Jersey. On the other hand, changes in those protective laws which have been so effective among the barriers against water-borne disease should be made slowly, and if public policy eventually brings about alterations of these laws, the changes should be made no faster than added protective measures in the way of treatment can be effectively secured to combat any increased hazards.

CHANGES IN POWER FOR PUMPING AT NEWPORT, R. I.

BY HAROLD WATSON.*

[*Read December 11, 1929.*]

A comparison of operating statistics will show that some relatively small steam-operated pumping stations require as large a personnel as do considerably larger plants. This fact, coupled with the high cost of repairs and maintenance of steam apparatus, no doubt gives cause for the serious consideration of the installation of electrical equipment operated by purchased current. In view of the recent trend towards using electric power for pumping, it is hoped that a description of the change from steam to electricity as worked out at Newport, R. I., may be of some interest.

The Newport Water Corporation supplies a population of about 27 000 in winter and 35 000 in summer. The average consumption, for the past few years, has been approximately 4 m.g.d. The supply is derived from six separate impounding reservoirs of varying size. The two largest of these are adjacent to the pumping station and provide the bulk of the raw-water storage. The remaining four smaller reservoirs are so located that while the water from two of them flows into the main reservoir by gravity, the water from the other two must be pumped over a considerable elevation. Consequently, two pumping stations are maintained. The smaller, auxiliary station is operated only when necessary. A filter plant is combined with the main station, and the raw water is raised from the ponds by low-lift pumps for filtration. The filtered water is pumped into such an arrangement of piping that it may go either directly into the distribution system, or up to a pressure-regulating and filtered-water-storage reservoir of 8 m.g. capacity.

Original Equipment. The steam apparatus originally employed for doing this work was provided in duplicate. The high-lift pumps were (1) an Allis-Chalmers triple-expansion engine and triplex pump and (2) a Corliss horizontal cross-compound engine with a Blake water end. The nominal capacity of both these pumps was 6 m.g.d. against a head of 155 ft. Most of the pumping was done with the first of these outfits, while the second was maintained as a stand-by. The low-lift steam equipment consisted of two Kingsford centrifugal pumps, directly coupled to Sturtevant engines, each with a maximum capacity of about 10 m.g.d. against a head varying from 20 to 30 ft. With these steam units there should also be included a Troy vertical engine directly coupled to a Root rotary blower for supplying air for cleaning the filters. The steam for operating all these engines was furnished by two 250-h.p. Babcock and Wilcox boilers, the delivery pressure being 150 lb. per sq. in.

*Newport Water Corporation, Newport, R. I.

Considerable preliminary investigation and study seemed to show that it would be advantageous to operate the station electrically. These studies were based on an average cost of coal of $8.50 per ton delivered and a charge for electrical current for off-peak use of 0.015 per K.W.H. Inasmuch as local conditions affect so much any comparisons of this nature, and this is particularly so in this case, questions, such as depreciation, taxes and capital invested, will be omitted and the situation considered only on the basis of coal and current used. The amount of water handled with the steam plant was determined only by pump displacement, with no allowance for slip. Consequently, the gallons pumped per pound of coal actually mean the total amount of work done by the steam incidental to the pumping of a given quantity of water. Although there was no accurate method of differentiating between the amount of power used by the high-lift pumps and low-lift pumps, an approximation was obtained by comparing the records of water pumped per pound of coal before and after the installation of the low-lift pumps. It was concluded that the low-lift pumps consumed between one quarter and one third of all the power produced. During the last few years there had been handled an average of 500 gal. of water per pound of coal, or in equivalent figures, one m.g. of water per ton of coal. As against this the estimated amount of electric current to pump one m.g. of water was about 800 K.W.H. With these figures as a basis, other factors were considered, such as repairs, lubrication, station lighting, and reduction in labor. In this connection it seemed advisable to take full advantage of the automatic features of electric pumping and to reduce attendance to a minimum. An example of this would be the electrification of the seasonally operated, auxiliary pumping station. This station at present consists of an Allis-Chalmers centrifugal pump coupled through reducing gears to a Moore steam turbine. The steam is supplied by a 134-h.p. boiler at a pressure of 150 lb. per sq. in. This station could be electrified and made to operate by remote control, eliminating all attendance. The conditions in this case seem ideal for automatic control, because in the event of a shutdown at the auxiliary station, the load would be automatically taken up by the main station until such time as the difficulty could be remedied. Of course the unit would be protected by equipment for shutting it down in the case of any unusual occurrence. Other features of the preliminary investigation were the availability of two separate power lines, and two separate sources of energy. Finally, it was decided to keep intact the steam apparatus for use as stand-by equipment.

Entering largely into these first studies was the question of finding a location for the electrically driven pumps. The necessity of constructing a new building, or an addition to the existing building was quite a factor. After some study, it was thought possible to place the main high-lift unit and the low-lift unit in a space comprising a part of the boiler room. Accordingly, this space was excavated to a depth of about 8 ft. in order that (1) the piping from the centrifugal pumps would run directly into existing

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Considerable preliminary investigation and study seemed to show that it would be advantageous to operate the station electrically. These studies were based on an average cost of coal of $8.50 per ton delivered and a charge for electrical current for off-peak use of 0.015 per K.W.H. Inasmuch as local conditions affect so much any comparisons of this nature, and this is particularly so in this case, questions, such as depreciation, taxes and capital invested, will be omitted and the situation considered only on the basis of coal and current used. The amount of water handled with the steam plant was determined only by pump displacement, with no allowance for slip. Consequently, the gallons pumped per pound of coal actually mean the total amount of work done by the steam incidental to the pumping of a given quantity of water. Although there was no accurate method of differentiating between the amount of power used by the high-lift pumps and low-lift pumps, an approximation was obtained by comparing the records of water pumped per pound of coal before and after the installation of the low-lift pumps. It was concluded that the low-lift pumps consumed between one quarter and one third of all the power produced. During the last few years there had been handled an average of 500 gal. of water per pound of coal, or in equivalent figures, one m.g. of water per ton of coal. As against this the estimated amount of electric current to pump one m.g. of water was about 800 K.W.H. With these figures as a basis, other factors were considered, such as repairs, lubrication, station lighting, and reduction in labor. In this connection it seemed advisable to take full advantage of the automatic features of electric pumping and to reduce attendance to a minimum. An example of this would be the electrification of the seasonally operated, auxiliary pumping station. This station at present consists of an Allis-Chalmers centrifugal pump coupled through reducing gears to a Moore steam turbine. The steam is supplied by a 134-h.p. boiler at a pressure of 150 lb. per sq. in. This station could be electrified and made to operate by remote control, eliminating all attendance. The conditions in this case seem ideal for automatic control, because in the event of a shutdown at the auxiliary station, the load would be automatically taken up by the main station until such time as the difficulty could be remedied. Of course the unit would be protected by equipment for shutting it down in the case of any unusual occurrence. Other features of the preliminary investigation were the availability of two separate power lines, and two separate sources of energy. Finally, it was decided to keep intact the steam apparatus for use as stand-by equipment.

Entering largely into these first studies was the question of finding a location for the electrically driven pumps. The necessity of constructing a new building, or an addition to the existing building was quite a factor. After some study, it was thought possible to place the main high-lift unit and the low-lift unit in a space comprising a part of the boiler room. Accordingly, this space was excavated to a depth of about 8 ft. in order that (1) the piping from the centrifugal pumps would run directly into existing

suction and discharge mains without vertical bends, and (2) the elevation of the low-lift pump would be such as to make the pump self-priming about one half of the time. In excavating this room it was found necessary to provide new footings under one partition wall and one main wall; also, since the floor elevation is well below ground-water level, to provide a reasonably water-tight floor and side walls. Water-tightness was obtained by making the concrete floor and lower part of the walls double with a coating of asphalt between. Above the ground-water level the walls were constructed of brick and carried up to the roof, making an entirely separate room, lighted both by inside and outside windows. This pump room which is 20 ft. in length, 14 ft. in width and 27 ft. in height now houses all the new electrical apparatus with the exception of a half-capacity high-lift pump and the motor operating the blower for the filters.

New Equipment. All the new electrical equipment was furnished by the Allis-Chalmers Company. It consists of three centrifugal pumps, of the double-suction type, with motors mounted on a common base, and of one 40-h.p. motor for driving the Root blower. The motors are all of the squirrel-cage induction type operating directly from a 2 300-volt line, at which voltage all the current is metered. This type of motor was chosen on account of its simplicity of construction, efficiency and ease of operation and because of the relatively small amount of attention it requires. Of these units, two are for high-lift pumping. The larger one has a capacity of 6 m.g.d. against a head of 158 ft., which is the maximum head encountered. This pump is driven by a 250-h.p. motor which is manually controlled. The overall efficiency of the unit is 77 per cent. at the rated load. The smaller of the high-lift units has a capacity of 3 m.g.d., and the motor is rated at 125 h.p. It is also manually controlled and has an overall efficiency of nearly 78 per cent. This half-capacity unit is sufficiently large to meet the requirements during a portion of the time, and its use tends to give more even operation than could be obtained with the 6-m.g.d. pump alone. There is also the possibility of running both together in an emergency for a short period of time. The automatic releases of these units are connected to switches operated by a float in the clear-water well and prevent the loss of suction and the pump running dry when the well is low. The capacities of these pumps are such that a considerable degree of elasticity is obtained by shifting from one to the other. It has been found possible to so accommodate the pumping to the demand that there is very little change in the reservoir level. The third, or low-lift unit has a minimum capacity of 7½ m.g.d. at the maximum head of 30 ft. It is driven by a 40-h.p. motor and has an overall efficiency at the rated point of 75 per cent. At the minimum head of about 20 ft. the discharge from this pump will increase to approximately 10 m.g.d. It was necessary, however, to have this range in order to get the full requirement for the filters during the periods of maximum lift. On account of the rather large percentage variation in capacity, a slip-ring motor was considered for this operation and also a main pump and a booster pump, for

the periods of low water. It was finally concluded that a single pump and induction motor would give good average efficiency and that the variations in head capacity and the fluctuations due to shutting down some of the filter units could be taken care of satisfactorily by intermittent operation, automatically controlled. This has the effect of keeping the main pumping unit extremely simple and placing the complications in the low-voltage control circuits and apparatus. These are easy to maintain in good order, and the necessary replacements are trifling. Since, due to its elevation about midway between high- and low-water levels, this pump is self priming only a part of the time, the automatic features had to include the priming. The equipment for this comprises a dry vacuum pump of 100 cu. ft. per min. capacity and a priming-control apparatus manufactured by the Barrett Haentzens Company. This apparatus primes the pump, prevents its starting umprimed, shuts the unit down in case of blocked discharge, broken discharge, or loss of suction, and rings an alarm if for any reason the priming operation exceeds a definite time limit. It is linked electrically with automatic starting and stopping devices and is primarily controlled by a float switch set in the basins supplying the filters. This switch is opened or closed by a difference in water level of 4 in. At such times as the pump is self priming, the water flows by gravity into the control apparatus and the priming operation is eliminated. Then the control circuit, when closed by the float switch, acts directly on the main starting switch. This automatic detail may perhaps be more clearly presented by the following description of the operating cycle.

When the level of water in the basins falls to the low point, the float switch closes the control circuit, and the priming pump is started. When the pump is primed, the priming-control apparatus acts to stop the vacuum pump and start the main pump through its starting switch. When the motor has come up to speed, the starting switch is opened and the running switch closed. In the circuit which holds the running switch closed are the devices, acting on differences in pressure and vacuum, which protect the outfit from any considerable variation from normal conditions. The cycle is complete when the water level in the basins rises and opens the switch.

There is another condition which has to be met with this apparatus. This is brought about at times of extremely low water level in one of the reservoirs. The suction line from this reservoir is a 20-in. pipe about 500 ft. long. In spite of the fairly large capacity of the dry vacuum pump, there is the possibility of its requiring several minutes to fill this pipe. There would be, of course, a proportionate drop in the basins below the required level. This undesired drop is prevented by a transfer switch, which disconnects the primer from the float switch and shifts it so that it operates at all times except when the main pump is running. The operating cycle is then changed as follows:

Immediately upon the shutting down of the main pump, the priming pump starts, primes the main pump and keeps it primed until such time as

it is ready to be started again. The result of this is that the water level in the basins is kept within the same definite limits regardless of the time required for priming.

The intermittent operation of this low-lift pump made it necessary to proportion the feeding of coagulants to the flow of water. Dry-feed machines, driven by ¼-h.p. motors are used to measure the alum, which is then conveyed through rubber hose to the pump suction. These motors have individual starters connected in the control circuit of the main pump and start and stop with it. Simultaneously, the water supply carrying the coagulant to the pump suction is shut off and opened by a push valve operated by a rod attached to the check valve in the discharge line of the main pump. All this automatic apparatus is equipped to operate also manually. In the event of failure of any part, or during a period of necessary repairs, operation can be immediately switched to hand control. All the foregoing apparatus combines to give a low-lift equipment which will adapt itself without attention to any condition that may arise in the rest of the plant.

The vacuum pump also primes the two high-lift pumps. To do this, it is switched temporarily to hand control. The low-lift control piping is valved off, and the primer is started by push button stations, located near the starting boxes of the high-lift units. In all cases there is interposed between the pump to be primed and the vacuum pump a 38-ft. water trap to prevent water being drawn into the latter.

There is a switchboard comprising six panels, whereon are mounted individual oil circuit breakers for each of the 2 300-volt motors, main switches for the various 220- and 110-volt control and lighting circuits, also ammeters, and a volt meter. There are provided watt-hour meters to enable the differentiation of the amount of current used by the several units. Matching the switchboard is the operating panel for the main oil-switch. This switch is of the mechanical remote-control type.

There are four 5-K.V.A. transformers. Three of these, connected in a bank, furnish current at 220 volts. The fourth, supplying current at 110 volts, is connected between the main oil-switch and the disconnect switches so that current for lighting may be had while the high-tension circuit is open.

The disposition of this electrical equipment in the pump room was made possible by utilizing three different levels. Platforms were run along two sides of the room; one, 9 by 14 ft. and the other 5 by 11 ft. Together these form a balcony about 8 ft. above the pump room floor and at approximately the same level as the steam-engine room floor. These platforms are supported on steel I-beams which are heavy enough to serve as supports for handling the equipment. Above this platform are more beams upon which rests a narrow planked runway 9 ft. above the balcony and 17 ft. above the floor. At this highest level are situated the incoming power lines, the disconnect switches, the main oil-switch, and the transformers. The disconnect switches can be thrown by a hook pole from the balcony, and the oil-switch is operated by remote control from the same point. On the balcony itself

is the switchboard, and on the main floor are the low-lift pump, main high-lift pump, and the priming apparatus; also the starting boxes for these units. This arrangement keeps all the exposed 2 300-volt lines on the upper level or in back of the switchboard, both of which places have been purposely made rather inaccessible. This arrangement cares for all but the half-capacity high-lift pump, to accommodate which, one of the steam-driven centrifugal pumps was removed, thus locating the electric unit just outside the door opening onto the balcony of the electric pump room. The motor for driving the blower was mounted on the wall beside it and connected by a belt to a sheave placed on the shaft of the blower engine. This engine was left intact so that it is ready at any time to be run by steam.

The discharge from all the pumps is measured by Bailey fluid meters. These were chosen (1) on account of their adaptability for installation in a small and limited space and (2) because of the satisfactory service derived from a similar meter placed several years ago on the wash-water line of the filters. The meters are of the flow nozzle type, and their guaranteed accuracy is within 2 per cent. or less.

The entire plant has now been in actual service about ten weeks. This is, of course, too short a period to permit of a safe comparison of the two methods of drive. Up to the time of writing, the electric units have functioned very smoothly and satisfactorily. The operating cost will be very close to that which was anticipated, and the cleanliness, ease of handling and elasticity are readily apparent. In the near future, a new impeller will be placed in the low-lift pump, giving a slight increase in capacity and efficiency, at the expense of a slight overload on the motor at certain times.

It might be interesting at this point to note the amount of the total electric current consumed which is applied to the various purposes. The high-lift pumps require about 83 per cent. and the low-lift about 14 per cent. This, when compared with the estimated use of steam for the same purposes shows a better proportioning of power between these two units. All the automatic devices and the pilot and control circuits require but about 2 per cent. of the current. The balance is taken up by the lighting circuit and by various losses, principally transformer losses.

Summary. A 6-m.g.d. steam-driven pumping plant has been duplicated by electrical equipment without disturbing the steam outfit to any extent. The new equipment has been compactly and conveniently housed without new buildings or additions to the original building. The changes were accomplished without interrupting the operation of the steam plant. The control of the electric units is such that it would be possible, if not practicable, for one man to handle both the pumps and the filters.

COLOR REDUCTION IN STORAGE RESERVOIRS.

BY CALEB MILLS SAVILLE.*

[*Read September 17, 1929.*]

The phenomena relating to reduction of color or decolorization of water by long storage in reservoirs, have been thoroughly treated by many able writers. It is, therefore, the aim of the author merely to record additional data which have come to his notice since his previous publication on this subject in this JOURNAL.[1]

The value of appearance of water for domestic use hardly can be overestimated. While of little spectacular moment, its influence is intimately connected in many ways with both financial and æsthetic considerations. The public now has been educated so thoroughly in what to expect from its water supply that it objects strongly to water that has a "brown look" no matter how perfect it may be from a sanitary viewpoint. Natural waters, particularly those of the northeastern states, are seldom without appreciable color, and to provide water of the appearance demanded, requires more or less treatment. Artificial treatment costs money, both for capital installation and for plant maintenance thereafter. If Nature can be maneuvered into giving some help in this matter of color removal, labor and other expense of operation can be correspondingly reduced.

It is thought that the late Frederick P. Stearns, Past President of this Association was the first to express, if not originate, the idea of color removal through natural agencies. Desmond FitzGerald and William E. Foss[2] so far as the author is aware, made the first really scientific investigation of these phenomena, and an elaborate study of the "Nature of Color in Water" was made by Thorndike Saville.[3] In his studies of color conditions pertaining to Hartford's (Conn.) water supply, Mr. Stearns compiled much valuable information concerning color removal by storage in reservoirs, and it seems desirable that these data be put in the record of the NEW ENGLAND WATER WORKS ASSOCIATON. (See Appendix A.)

The subject of "Decolorization of Water" was thoroughly discussed before the American Society of Civil Engineers in 1901[4], and in 1915, Ralph H. Stearns[5] presented a paper to this Association entitled "Decolorization of Water by Storage," in which this matter was quite fully treated, especial mention being made of conditions in Wachusett Reservoir. A very interesting and valuable paper on this subject was presented to the American Water Works Association by Robert Spurr Weston.[6] In his discussion of

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1"Color and Other Phenomena of Water," JOUR. N. E. W. W. A., Vol. 39, No. 2 (1925).
2*Jour. Franklin Institute*, December, 1894.
3JOUR. N. E. W. W. A., Vol. 31, p. 78, 1917.
4*Trans. Am. Soc. C. E.*, Vol. 46, p. 141.
5JOUR. N. E. W. W. A., Vol. 30, p. 20.
6*Jour. A. W. W. A.*, Vol. 19, p. 416.

the paper by C. M. Saville[1], Weston shows by diagram an apparent relationship between color removal and storage, which, taken with that presented by R. H. Stearns, is of considerable help in guiding judgment when the prediction of the ultimate color to be expected in a new storage reservoir is under consideration. In Whipple's "Microscopy of Drinking Water"[2] under title of "Pre-Storage" (pp. 371–375), credit is given to X. H. Good-

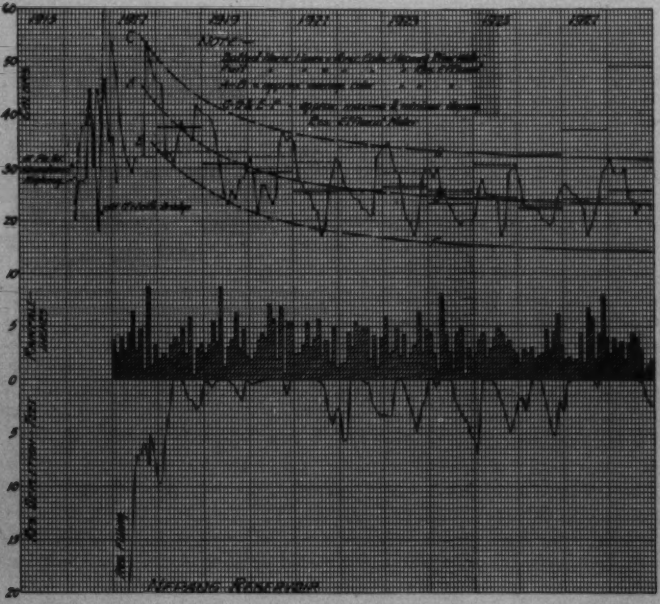

FIG. 1. — COLOR, RAINFALL AND DEPLETION.
Nepaug Reservoir, 1917–1928.

nough[3] for abstracts from his studies that are of very great importance. The relation of albuminoid ammonia and oxygen consumed is very conveniently shown by diagrams in the discussion on "Decolorization of Water"[4]. The latest contribution to this subject, "Decolorization of Water by Storage in Clean-Bottomed Reservoirs"[5] brings down to date, in a critical study by Kennison, the data collected from the Wachusett

[1]JOUR. N. E. W. W. A., Vol. 39, p. 145.
[2]Fourth Edition, revised by G. M. Fair and M. C. Whipple.
[3]Chief Engineer, Mass. State Board of Health.
[4]*Trans. Am. Soc. C. E.*, Vol. 46, p. 141.
[5]JOUR. N. E. W. W. A., Vol. 43, No. 2, p. 90.

Reservoir of the Metropolitan (Boston) Water Works, and adds important information furnished by the peculiar conditions existing in Suntaug Lake. In 1925, the author compiled[1] some data and is now able to add further facts in this discussion. While Kennison took the phenomena of "clean-bottomed reservoirs" for his subject, the matters presented by the author refer to reservoirs which were not originally stripped of sod and loam, although carefully cleared of all standing vegetation.

In a report (1917) on the color to be expected from the Nepaug Reservoir of the Hartford Water Supply Works, then under construction, Frederick P. Stearns stated that as a result of his observations, thirteen years was about the time required for an unstripped reservoir to age to a point where conditions in the unstripped reservoir would be somewhat analogous to those in a stripped reservoir, so far as relates to odors, organisms and albuminoid ammonia. In regard to color, Stearns stated that the aging of unstripped reservoirs proceeded much more rapidly from the conditions existing at the time of first filling to those of a clean-bottomed reservoir. He gave a number of examples with a range of from 3 to 10 years, with an average of six for accomplishing this result (see Appendix A), and allowed three or four years first for readjustment of conditions.

Figure 1, recording changes in the color of water in the Nepaug Reservoir[2], is presented as an example of decolorization of water in an unstripped reservoir, but one which has now been sufficiently long in service (1917–1928 incl.) to qualify under the Stearns dictum for similarity to a reservoir with a cleaned bottom. In one of his reports[3], Stearns calls attention to the similarity of physical conditions between this reservoir (Nepaug) and those of the Wachusett Reservoir. This fact makes a comparison of the data and results of Kennison's study of particular interest because there is now available information carefully gathered from two reservoirs operating under approximately similar conditions, one of them having a cleaned bottom from its beginning and the other, although starting with an unstripped bottom, having, through a period of aging, attained a condition similar to that of its stripped prototype.

In Table 1 is to be found a summary of the color and other conditions observed at the Nepaug Reservoir. Only brief discussion is necessary in presenting these facts.

If we omit consideration of the first three years (1917–1919 incl.) after the reservoir was put in service, on the ground that certain unusual factors were in process of becoming reconciled to the changed conditions of open air to under water, it is possible to deduce some interesting results for comparison with those deduced from action in the Wachusett Reservoir.

For the nine years (1920–1928 incl.) the average apparent color reduction weighted for area of the several inflowing streams is about 19 per cent.,

[1]Jour. N. E. W. W. A., Vol. 39, p. 145.
[2]Hartford (Conn.) Water Supply capacity about 9.5 billion gallons.
[3]See Appendix A.

while the real reduction in color between the entering water, Nepaug River, and that drawn off at the effluent gatehouse is about 24 per cent. due to storage and dilution.

TABLE 1. — NEPAUG RESERVOIR AND TRIBUTARY STREAMS.
ANNUAL AVERAGE COLORS.
(Reservoir Filled in 1917.)

Year.	Rainfall In. (Bakersville).	Nepaug River, 26.57 Sq. Miles.		Phelps Brook, 2.90 Sq. Miles.		Clear Brook, 1.05 Sq. Miles.		Nepaug Res.		Color Reduction. per cent.	
		Disch. Sec. Ft. per Sq. Mile.	Color.	Disch. Sec. Ft. per Sq. Mile.	Color.	Disch. Sec. Ft. per Sq. Mile.	Color.	*Influent Color.	Effluent Color.	Weighted Average.	Nepaug River.
1917	43.04	1.86	32	1.52	41	1.71	15	29.9	35.7	...	...
1918	45.16	1.62	33	1.29	44	1.63	14	30.7	38.2	...	...
1919	49.58	1.93	33	1.68	45	1.94	17	31.0	31.1	...	...
1920	53.53	2.48	32	2.32	44	1.98	16	30.4	29.4	3.4	8.1
1921	40.70	1.57	31	1.60	37	1.91	15	29.2	25.8	11.6	16.8
1922	44.46	1.50	34	1.69	42	1.51	15	31.2	25.7	17.7	18.6
1923	44.20	1.87	29	2.01	35	1.77	14	27.2	26.2	3.7	9.6
1924	39.51	1.60	26	1.71	33	1.65	14	24.4	23.1	5.3	11.2
1925	41.78	1.34	30	1.47	36	1.25	12	27.3	24.4	10.6	18.7
1926	41.79	1.44	33	1.45	35	1.70	12	29.6	21.7	26.7	34.4
1927	52.71	2.32	37	2.46	49	2.32	12	34.8	24.1	30.7	34.9
1928	45.51	1.88	49	1.90	48	2.67	11	43.7	25.7	41.1	47.6
Annual Average 1920–1928 Incl.	44.91	1.78	35	1.85	40	1.86	13	30.8	25.0	16.8	22.2

*Weighted, and using color "0" for water falling on reservoir surface.

NOTE: The above table originally appeared as Table VI in a paper entitled, "Color and Other Phenomena of Water from an Unstripped Reservoir in New England," by C. M. Saville. JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, Vol. XXXIX, No. 2, pages 145–170 incl.

Contributing Areas:

Nepaug River	26.57 Sq. Miles.	83.4 per cent.
Phelps Brook	2.90 Sq. Miles.	9.1 per cent.
Clear Brook	1.05 Sq. Miles.	3.3 per cent.
Reservoir Surface	1.33 Sq. Miles.	4.2 per cent.
	31.85 Sq. Miles.	100.0 per cent.

These results[1] are arrived at as follows:

Area.	Average Color.	Area Sq. Miles.	Per cent. of Total Area.	Per cent. of Land Surface.
Nepaug River	35 times	23.67 = 828	74.3	77.6
Phelps Brook	40 times	2.90 = 116	9.1	9.5
Clear Brook	13 times	1.05 = 14	3.3	3.4
Reservoir Shore	13 times	2.90 = 38	9.1	9.5
Reservoir Surface	0 times	1.35 = 0	4.2	..
		31.87 996		

I. For Weighted Average:

Average Color of Entering Water	31.3[2]
Average Color of Effluent	25.0
Difference (Apparent Reduction of Color)	6.3 or 19.3 per cent.

II. For Land Surface Only:

Nepaug Run-off:	
Average Color of Entering Water	33[3]
Average Color of Effluent	25
Difference (Apparent Reduction of Color)	8 or 24.2 per cent.

While these studies of color removal, like those of other natural phenomena, are interesting, it must be borne in mind that there are so many factors and varying local conditions which influence color removal, that the figures given should be taken only as a guide to judgment.

It seems probable that beside storage, and possibly magnifying the effect of storage, such matters as depth of drawdown of a reservoir at critical periods, topography, geological conditions of rocks, soil and subsoil and frozen ground all have so marked an effect, that the utmost caution should be exercised in making use of actual figures obtained from a study of any particular watershed and applying them to another. Application should be deferred until a thorough study of the characteristics of each has been made. Such ground conditions and seasonal run-off as might be contrasted in Maine and New Jersey for example, might give very different results and offer partial explanation of the seemingly excessive reduction in color of the Boonton Reservoir noted in Weston's diagram which has been referred to previously.

Again, these physical conditions may be modified by chemical factors such as albuminoid ammonia, dissolved oxygen and hydrogen ion concentration, and the results in several reservoirs be entirely different, although storage and length of period of aging may be comparable.

To follow out this thought somewhat, let us consider the Nepaug River watershed as an example. This watershed contributes about 75 per cent. of the entire run-off of the reservoir basin. During the seven years, 1920–

[1] Land area only.
[2] For Annual Average Colors see Table 1 and for Monthly Colors, Table 2.
[3] Difference between 30.8 of Table 1 and 31.3 average colors is due to the inclusion of Reservoir Shores in latter with assumed color of Clear Brook.

1928, maximum rainfalls obtained in 1920 with 51.8 in., and in 1927 with 51.1 in. The corresponding run-offs were respectively 33.9 and 31.5 in., and the annual average colors were 32 and 37. The annual average reduction in color between the reservoir influent and effluent, however, was 8.1 per cent. in 1920 and 34.9 per cent. in 1927. In 1920, the rainfall was fairly uniformly distributed throughout the year, while in 1927, the rainfall was considerably below normal until the latter part of July, when large amounts fell, particularly in the last three months of the year. On account of these happenings, the run-off for 1927 was above or equal to the entire rainfall during the period January to June, and therefore large quantities of ground water flowed into the reservoir instead of surface water. In 1920, although the total rainfall was somewhat larger than that of 1927, the run-off was consistently below but parallel with the rainfall. The effect of this condition is perhaps best illustrated by comparison of the monthly records for these two years and the year of minimum rainfall, 1924:

TABLE 2. — MONTHLY RAINFALL, RUN-OFF AND COLOR, NEPAUG RESERVOIR, 1920, 1927 AND 1924.

Month.	1920.				1927.				1924.			
			Color —P.P.M.				Color —P.P.M.				Color —P.P.M.	
	Rainfall. in.	Run-off. in.	Influent.	Effluent.	Rainfall. in.	Run-off. in.	Influent.	Effluent.	Rainfall. in.	Run-off. in.	Influent.	Effluent.
January	2.59	0.78	12	32	2.22	2.11	25	27	4.11	4.01	22	30
February	4.35	1.50	18	28	2.96	1.88	25	26	2.26	0.92	22	28
March	4.19	8.39	26	21	1.92	4.45	28	25	1.02	1.98	23	30
April	4.02	5.51	25	27	2.15	2.06	28	25	7.76	6.17	27	25
May	3.47	2.99	35	27	5.41	2.85	37	23	4.54	3.72	33	25
June	6.47	2.72	38	25	2.53	1.15	41	22	2.70	1.38	24	23
July	4.88	1.99	40	23	6.93	1.53	51	17	1.09	0.32	25	22
August	3.39	0.93	47	25	6.71	2.74	41	19	4.20	0.40	30	20
September	7.86	0.93	33	34	1.85	1.12	45	22	4.77	0.58	29	19
October	0.66	1.79	38	37	5.10	1.76	52	24	0.94	0.60	27	20
November	4.63	2.24	43	35	8.64	5.95	38	29	3.15	0.69	25	20
December	5.27	4.15	34	36	4.72	3.91	43	30	1.91	1.01	24	20
Annual Average	51.8	33.9	32	29	51.1	31.5	38	24	38.5	21.8	26	24

NOTE: The rainfall at Nepaug Dam is used here instead of Bakersville used in Table 1. The rainfall and run-off for the year 1924 were the least for the period under consideration (1920–1928) with a large percentage of the rainfall passing into the ground instead of flowing off the surface. A portion of this run-off later appeared in the streams as spring water, which, having passed slowly through the natural earth filter, had a color 31.8 per cent. of that flowing in the stream in 1927. Due to storage and its accompaniments, the effluent water, however, had the same color.

From what has gone before, it is perhaps unnecessary to state that the reduction observable between the color of the entering stream and that of the effluent from a storage reservoir is measurably affected by the inflow of low-colored water from springs and rainfall on the surface of the reservoir as well as by storage and its accompaniments.

Table 3 is a summary of the monthly average colors that have been observed in the effluent of the Nepaug Reservoir, 1917 (date of first filling) to and including 1928. It is of interest to compare these actual results with the colors which were predicted by F. P. Stearns in 1917. (See Appendix A.)

TABLE 3. — MONTHLY COLOR OF WATER — NEPAUG RESERVOIR AT PHELPS BROOK DAM, 1917–1929.

Results are parts per million of color.

Year.	Jan.	Feb	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Av'ge.
1917	54	47	38	34	31	29	32	32	32	54	50	47	40
1918	46	46	32	33	31	35	39	37	...	35	42	41	38
1919	40	40	39	36	30	25	23	26	24	28	28	30	31
1920	32	28	21	27	27	25	23	25	34	37	35	36	29
1921	35	28	27	25	25	22	22	17	19	26	29	32	26
1922	31	27	26	25	24	24	22	22	21	21	32	33	26
1923	34	35	32	29	29	23	20	20	17	20	28	30	26
1924	30	28	30	25	25	23	22	20	19	20	20	20	24
1925	21	25	28	25	26	25	24	18	20	29	31	30	25
1926	27	23	23	22	22	22	19	18	18	19	24	25	22
1927	27	26	25	25	23	22	17	19	22	24	29	30	24
1928	32	29	29	29	30	24	24	22	24	23	23	22	26
1929	23	24	...	...	...	...	...	...	...	...	...	...	...

In spite of the very satisfactory reduction in color in the Nepaug Reservoir and its approach to the color predicted by Messrs. Stearns and Weston when it was first put in service, its color reduction, after a decade of service, has not equalled that of the Wachusett Reservoir.

While storage is now recognized to be a factor in color removal and while the length of period of storage probably plays a large part in this phenomenon, it seems probable that as in the case of other nature phenomena, there are other factors which add mightily to the complexity of the problem. Until these, too, are given proper weight, it will be impossible to predict with any degree of certainty what color removal may be expected.

In view of the tendency to follow copy, it seems desirable to emphasize the futility of direct comparisons. The factors, dilution and precipitation on lake surface undoubtedly have a very great effect on decolorization. With two lakes of the same capacity, one long, narrow and deep, the other broad and shallow, one should expect entirely different results in decolorization by storage, and if one of the lakes was in a rocky or heavy soil valley and the other in a locality where gravel and sand of the glacial drift predominate, still further modifications might be expected. There appears to be no general rule to follow in predicting decolorization of water in stor-

age reservoirs, except that of experience and knowledge of local conditions. Many of the elements that must be used in predicting run-off from an ungaged area, compared with those used for a gaged one, apply also to color predictions. It is just as dangerous in one case as in the other to assume that the result known to have been obtained in one case can be obtained in another without modifications based on the comparative differences of the two areas.

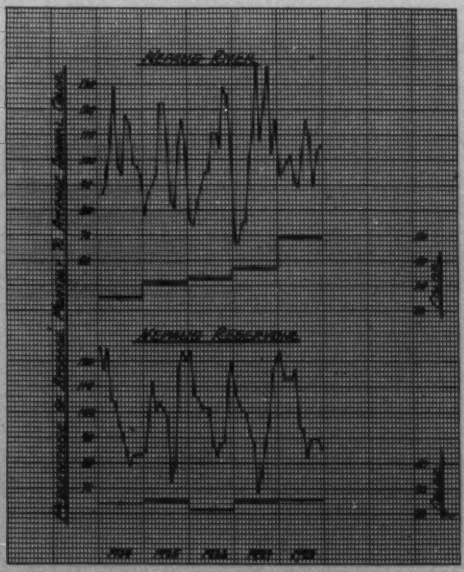

FIG. 2. — PERCENTAGE RATIOS OF MONTHLY TO ANNUAL COLORS.
Nepaug River and Nepaug Reservoir, 1924–1928.

In his 1925 paper,[1] the author presented a diagram (Fig. 8, p. 158) showing reduction of color conditions in the Nepaug Reservoir, 1917–1923. In Figure 1 of this paper, the period has been extended to 1929. The estimated average annual color is shown by the line "AB" and the trend of this line indicates that the ultimate color of this reservoir has about been reached and may be placed at 23 p.p.m. A comparison of these colors with those predicted by Frederick P. Stearns in March, 1917 (See Appendix A) is given in the following table.

Figure 2 shows the percentage ratios of monthly colors to the average

[1]Jour. N. E. W. W. A., Vol. 39, p. 145.

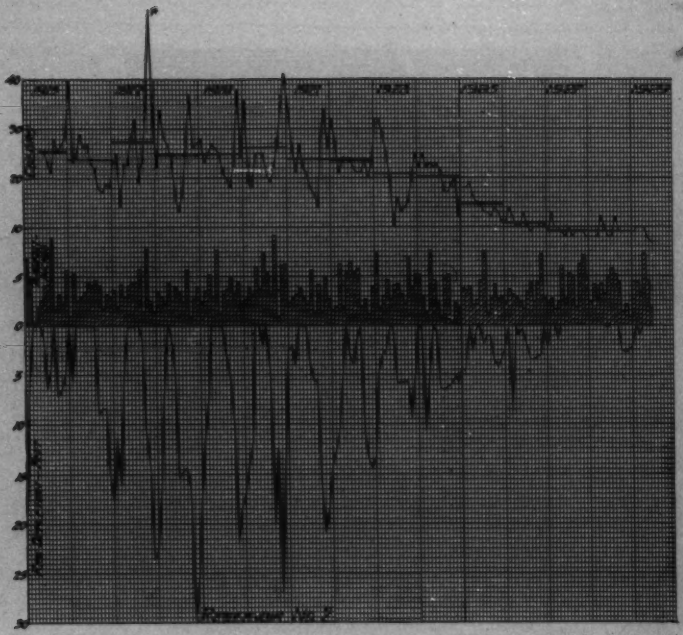

FIG. 3. — COLOR, RAINFALL AND DEPLETION.
Reservoir No. 2, 1915–1929.

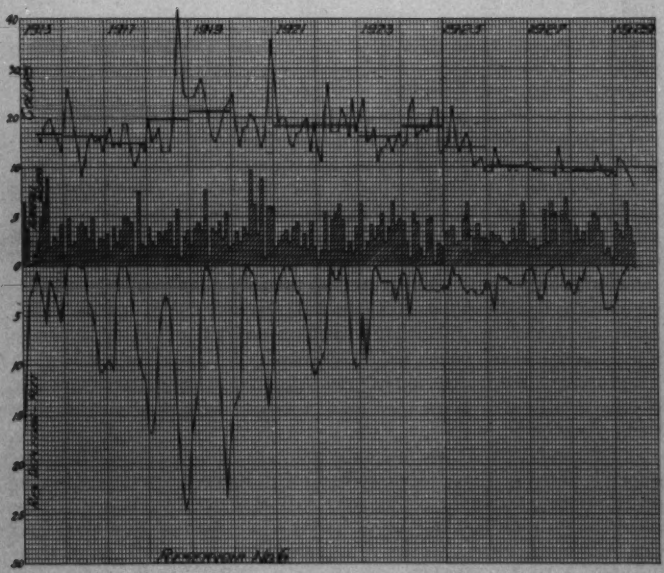

FIG. 4. — COLOR, RAINFALL AND DEPLETION.
Reservoir No. 6, 1915–1929.

annual color of the water of the Nepaug River, supplying 75 per cent. of the water to the reservoir, and the water in the effluent pipes from the reservoir. Figures 3 and 4 refer to conditions in two small reserve storage

Year.	Actual Colors. Fig. 1.	F. P. Stearns' Prediction, 1917.	Year.	Actual Colors. Fig. 1.	F. P. Stearns' Prediction, 1917.
1917.....	46	46	1923.....	25	24
1918.....	38	43	1924.....	24	..
1919.....	32	34	1925.....	24	..
1920.....	29	30	1926.....	24	..
1921.....	27	27	1927.....	23	..
1922.....	26	25	1928.....	23	..

reservoirs of the supply works. During late years, the water in these reservoirs has been held for emergencies and for æsthetic purposes in the reservoir park area. It is interesting to note the very low color of the water in these reservoirs since they have ceased to be drawn on for any considerable amount. Figures 3 and 4 give the color of the reservoirs at the outlet works. The upper lines in each of the last two diagrams give the color variations, and the shaded portion, the rainfall by months. The lowest irregular line shows the condition of the reservoir due to drawing water. Note the high colors, 1917–1921 while large amounts of water were being drawn, and the low colors 1926–1928 when very little water was used. This condition is apparent in both reservoirs and indicates the desirability of long storage even in old reservoirs. Both of these reservoirs are over thirty years old.

The conditions of these reservoirs (No. 2 and No. 6) conform in a considerable degree to those laid down by Karl R. Kennison[1] as the criteria for study of the phenomena of decolorization of water by storage. These reservoirs, in their building, were cleared of all standing vegetation, and this, with their age and absence of much artificial drawdown, places them in a class analogous to that of natural ponds, in showing the effect of storage. The color of the entering brooks to these reservoirs was not taken, but the results from storage appear in the colors in both reservoirs, averaging about 25 p.p.m. (1915–1922 incl.) while the reservoirs were in full service and subject to considerable drawdown as compared with the lessening color (1923–1925 incl.) during the period of intermittent draft and the greatly reduced color, about 10 p.p.m., since the reservoirs have been held as a reserve.

The watersheds of these reservoirs are comparatively small. No. 2 Reservoir has a watershed of 1.40 sq. miles of which 1.33 sq. miles are land. No. 6 Reservoir has a watershed of 2.04 sq. miles of which 1.82 sq. miles are land.

[1] "Decolorization by Storage in Clean-Bottomed Reservoirs," Jour. N. E. W. W. A., March, 1929, p. 60.

APPENDIX A.

Abstracts from Reports of Frederick P. Stearns in Connection with Water Supply Problems of Hartford, Conn.

July 30, 1917.

Thirteen years is mentioned as about the time required for a reservoir to age, so that the conditions are somewhat like those of a stripped reservoir. I took this hastily from the following table of reservoirs containing little swampy area, the figures giving the number of years to the time when the reservoir behaved much like a reservoir which had been stripped.

Reservoir.	Odors.	Organisms.	Albuminoid Ammonia.	
			Suspended.	Total.
Brockton	17	21	11	11
Fitchburg, Scott	38+	38+	38+	38+
Holyoke, White	2	0	1	1
Quincy	8	6	11	11
Springfield, Borden Brook	2	0	4	4
Winchester, South	7	10	10	12
Average of Very Variable Results	12	13	13	13

You will note that this table relates wholly to odors, organisms and albuminoid ammonia, and I think it correctly represents, as nearly as one can judge of these uncertain things, the length of time for the aging of a good reservoir in these respects. The time appears to be very variable, and may be longer or shorter.

In regard to color, however, the aging is reached much more quickly. I have plots of many unstripped reservoirs from the time they were first filled, and they show that after comparatively few years the color is uniform from year to year. The following are the results of different reservoirs where the observations were available from the beginning:

Reservoir.	Age When Normal Color Conditions Were Reached.	Remarks.
Holyoke, Whiting Street	9 years	
Lynn, Glen Lewis	10 years	
Lynn, Walden Pond	10 years	
Marlboro, Millham Brook	4 years	Small storage capacity.
Quincy	3 years	
Southbridge, Hatchet No. 4	3 years	
Springfield, Borden Brook	4 years	
Winchester, Middle	6 years	Very swampy.
Winchester, South	3 years	
Average	6 years	

The terms of years vary from 3 to 10, and average 6.

I believe that at the Nepaug Reservoir the average colors will not be higher than those at the inlet for more than about six years, and very likely for only about four or five years. I do not mean by this that there will not be stagnation in the bottom which will bring a moderate amount of dark colored water to the surface for some years longer, but not enough to produce very high color and this color will disappear rather quickly. It is clearly the case that color trouble does not last as long with an unstripped reservoir.

I have attempted to estimate the color of the Nepaug Reservoir water at the Phelps Brook Dam, by taking the records of four other reservoirs which have been filled and making allowances for the difference in the color of the entering water and for other features. For instance, a shallow reservoir like the Whiting Street Reservoir at Holyoke will overturn a month or two earlier than a deep reservoir like the Nepaug. Hence, in applying the Whiting Street Reservoir results to Nepaug I have assumed that the dark colors will come later in the season.

The best basis for the color of the water entering Nepaug Reservoir appears to be the color of the outflow at Phelps Brook and at Nepaug Brook, as observed for 1916, except that as the outflow color went up in December after ponding began I have used the inflow color for that month. This gives me a direct average of 30 for Nepaug Brook and of 36 for Phelps Brook, or a weighted average for the two of 31.

The record for 1915 gives higher colors, but this was a year of unusually high colors, a point to which I called your attention when you were here. Making the same deduction that would be necessary for the same months to reduce the observed influent colors at Wachusett, to the average for a series of years checks the 1916 results. Similarly, the 1917 inflows, as far as they have been taken, support the 1916 observations.

As the colors are somewhat lower in the spring than at other times and the bulk of the water comes in at that time, I have thought it safe to say that the color of the water entering your reservoir will average as low as 30.

You may note that in the above estimate I have used the outflow in preference to the inflow, because it seems to me that the outflow represents more nearly the total quantity of water which will enter the reservoir.

My estimate of the color of the water, by months, in the Nepaug Reservoir at the head of the main pipe for the first seven years is based upon the following reservoirs:

Springfield, Borden Brook
Holyoke, White
Holyoke, Whiting Street
Winchester, South

The estimated color of water in the Nepaug Reservoir is represented by the averages below:

Reservoir.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
First Year.												
Borden Brook	30	30	30	30	30	30	34	40	45	65	65	77
Holyoke, White	30	30	30	30	30	30	42	75	105	110	85	75
Holyoke, Whiting Street	30	30	30	30	30	30	35	55	60	65	65	56
Winchester, South	30	30	30	30	30	30	33	50	50	50	58	55
Average	30	30	30	30	30	30	36	55	65	70	68	66
Second Year.												
Borden Brook	65	60	50	40	30	30	30	30	30	40	50	55
Holyoke, White	65	55	40	30	30	30	42	48	55	52	52	47
Holyoke, Whiting Street	43	35	30	30	30	30	35	45	52	55	45	45
Winchester, South	52	50	46	36	30	30	30	36	40	50	63	58
Average	56	50	42	34	30	30	34	40	44	49	53	51
Third Year.												
Borden Brook	50	45	40	35	30	30	28	26	30	35	43	48
Holyoke, White	42	37	32	30	30	30	35	39	43	43	43	42
Holyoke, Whiting Street	40	32	30	30	30	28	26	23	23	26	35	35
Winchester, South	50	48	46	36	30	30	30	31	34	40	45	42
Average	46	41	37	33	30	30	30	30	33	36	42	42
Fourth Year.												
Borden Brook	46	42	38	34	30	30	27	24	27	35	40	45
Holyoke, White	42	35	32	30	..	..	..	..	..	..	..	..
Holyoke, Whiting Street	33	30	29	28	27	26	24	22	23	26	35	34
Winchester, South	40	38	35	32	30	26	24	22	22	24	35	32
Average	40	36	34	31	29	27	25	23	24	28	37	37
Fifth Year.												
Borden Brook	44	40	37	33	29	27	24	21	21	26	30	34
Holyoke, Whiting Street	32	30	29	29	27	25	23	21	20	24	30	30
Winchester, South	30	30	29	28	26	24	22	21	21	23	28	26
Average	35	33	32	30	27	25	23	21	21	24	29	30
Sixth Year.												
Borden Brook	34	31	29	28	27	25	22	19	18	22	26	30
Holyoke, Whiting Street	29	29	28	28	27	25	23	21	20	24	30	30
Winchester, South	25	24	24	25	25	24	22	21	21	23	27	24
Average	29	28	27	27	26	25	22	20	20	23	28	28
Seventh Year.												
Borden Brook	30	29	28	27	25	..	..	..	..	..	..	..
Holyoke, Whiting Street	29	28	27	26	24	22	20	18	17	21	27	26
Winchester, South	22	21	21	22	23	24	22	20	20	23	27	24
Average	27	26	25	25	24	23	21	19	19	22	27	25

SUMMARY OF AVERAGES, REPRESENTING NEPAUG RESERVOIR COLORS.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Av.
First year, 1917	30	30	30	30	30	30	36	55	65	70	68	66	45
Second, 1918	56	50	42	34	30	30	34	40	44	49	53	51	43
Third, 1919	46	41	37	33	30	30	30	30	33	36	42	42	36
Fourth, 1920	40	36	34	31	29	27	25	23	24	28	37	37	31
Fifth, 1921	35	33	32	30	27	25	23	21	21	24	29	30	28
Sixth, 1922	29	28	27	27	26	25	22	20	20	23	28	28	25
Seventh, 1923	27	26	25	25	24	23	21	19	19	22	27	25	24

July 31, 1917.

It is well known that when an unstripped reservoir is first filled the water acquires, after standing for a time, a considerable amount of color, chiefly from the vegetable matters which have been flooded. On the other hand, some of the color taken up is removed by the bleaching process which goes on in reservoirs where the water is stored for a long time, as in the Nepaug Reservoir. In the early years more color is taken up than is removed by bleaching.

As the years pass, the amount of coloring matter acquired from the bottom and sides of the reservoir diminishes, while the bleaching process is continually going on, so that after a term of years of somewhat uncertain length there is as the result of storage a decided diminution in the color of the water which enters the reservoir.

Fortunately, there has been a large number of continuous observations of the color of water in reservoirs, giving the full history in this respect from the time of the first filling of several which are fairly comparable with the Nepaug Reservoir. In making an estimate of the color of water in a new reservoir, due allowance has to be made for the different characteristics of different reservoirs, notably differences in the color of the water which supplies them.

The Nepaug Reservoir is one that is large in proportion to the quantity of water entering it, as it will hold about 80 per cent. of an average year's flow. Hence, the period of detention is long enough for the water to take up matter from the bottom and sides of the reservoir and for a large amount of bleaching.

The reservoirs where continued observations of color are available, which compare most nearly with the Nepaug Reservoir, are the Borden Brook Reservoir of the Springfield Water Works, the White and the Whiting Street Reservoirs of the Holyoke Water Works, and the South Reservoir of the Winchester Water Works. The relative amount of storage in comparison with the quantity of water entering is indicated quite nearly by the storage capacity per sq. mile of drainage area, which is as follows:

Reservoir.	Storage per Sq. Mile of Drainage Area.
Nepaug	296 m.g.
Borden Brook	313 m.g.
Whiting Street	370 m.g.
White	163 m.g.
South	743 m.g.

There are records of other reservoirs of smaller storage capacity per sq. mile of drainage area, among which may be mentioned:

Reservoir.	Storage per Sq. Mile of Drainage Area.
Marlborough, Millham Brook	126 m.g.
Quincy	116 m.g.
Southbridge, Hatchet No. 4	76 m.g.

The period of detention in these reservoirs during the wetter months of the year is so short as to make the records generally inapplicable to the Nepaug Reservoir, and the information offered by the first group of reservoirs will be used almost exclusively.

The filling of the reservoirs of the first group began in December or January, so that the first year of filling corresponds well with the calendar year. This is the case also at Nepaug, where the filling began toward the end of 1916.

The first series of tables which follow shows the observed colors of the water in the four reservoirs of the first group by months and years. During a part of the time the colors were determined bi-monthly, and to complete the tables the colors for intermediate months have been interpolated.

The following table might be called a rough estimate of the probable color of the water in the Nepaug Reservoir for the first seven years, but as it does not take into account the differences in the color of the water entering the reservoirs or the character of the reservoirs themselves an estimate which probably will be more nearly correct can be made.

A study of the results of your observations of the color in the streams which feed the Nepaug Reservoir shows that the average color of the entering water will be 30.

Monthly observations are available of the color of the water of the principal stream entering the Borden Brook Reservoir, and the average color for the first six years was 77. The average color of the water entering this reservoir is probably somewhat less, and may be taken as about 60.

The color of the water entering the Whiting Street Reservoir, based on observations for two years before the reservoir was built, is 33, so that this reservoir does not differ materially from the Nepaug Reservoir in the matter of the color of the inflowing water. It differs, however, in that it has much less depth, a condition which is likely to cause more color to be taken up from the reservoir bottom but which is also more favorable for the bleaching of the water.

COLOR OF WATER IN UNSTRIPPED RESERVOIRS DURING THE FIRST AND SUBSEQUENT YEARS.

Reservoir.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Av.
First Year.													
Borden Brook	90	72	62	56	54	53	56	66	63	77	85	100	..
Holyoke, Whiting Street	46	35	9	14	18	22	33	55	58	70	58	46	..
Holyoke, White	..	..	..	20	20	30	40	75	105	110	75	†	..
Winchester, South	..	..	..	..	..	..	..	58	49	39	58	55	..
Averages	68	54	36	30	31	35	43	64	69	74	69	67	53
Second Year.													
Borden Brook	90	94	90	64	60	60	58	58	55	62	72	70	..
Holyoke, Whiting Street	33	18	14	22	26	26	39	33	52	55	38	33	..
Holyoke, White	18	18	17	20	21	24	35	40	45	42	42	37	..
Winchester, South	52	52	46	52	46	36	32	33	36	46	63	58	..
Averages	48	46	42	40	38	37	41	41	47	51	54	50	45
Third Year.													
Borden Brook	70	62	65	50	45	45	40	35	36	37	52	54	..
Holyoke, Whiting Street	33	24*	14	20*	26	23*	20	22*	24	25*	26	24*	..
Holyoke, White	26	31	28	23	22	20	23	27	35	32	32	30	..
Winchester, South	42	46*	49	44*	39	30*	22	23*	24	30*	35	29*	..
Averages	43	41	39	34	33	30	26	27	30	31	36	34	34
Fourth Year.													
Borden Brook	54	53	52	52	47	55	40	40	35	41	72	72	..
Holyoke, Whiting Street	22	23*	24	29*	33	30*	28	35*	42	38*	33	30*	..
Holyoke, White	32	19	25	19	22	20	20	21	†	..	..	..	..
Winchester, South	23*	18	25*	33	32*	30	21	22	22	22	30	24	..
Averages	33	28	32	33	34	34	27	30	33	34	45	42	34
Fifth Year.													
Borden Brook	80	60	15	10	41	44	40	27	27	30	41	44	..
Holyoke, Whiting Street	26	29	27*	25*	24	30	29*	27*	26	26	30*	33	..
Winchester, South	41	42	18	13	26	18	20	20	20	20	26	24	..
Averages	49	44	20	16	30	31	30	25	24	25	32	34	30
Sixth Year.													
Borden Brook	45	40	38	38	37	36	39	38	60	50	50	41	..
Holyoke, Whiting Street	30	32*	34	30*	26	26*	26	28*	30	26*	22	22*	..
Winchester, South	24	20	24	30	30	27	26	20	24	20	31	20	..
Averages	33	31	32	33	31	30	30	29	38	32	34	28	32
Seventh Year.													
Borden Brook	64	40	45	27	42	38	42	58	47	60	60	64	..
Holyoke, Whiting Street	22	20*	18	22*	26	24*	21	22*	22	27*	32	26*	..
Winchester, South	22	18	18	22	20	18	14	14	14	20	36	40	..
Averages	36	26	27	24	29	27	26	31	28	36	43	43	31

*Interpolated.
†Reservoir Emptied.

SUMMARY OF AVERAGES.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Av.
First	68	54	36	30	31	35	43	64	69	74	69	67	53
Second	48	46	42	40	38	37	41	41	47	51	54	50	45
Third	43	41	39	34	33	30	26	27	30	31	36	34	34
Fourth	33	28	32	33	34	34	27	30	33	34	45	42	34
Fifth	49	44	20	16	30	31	30	25	24	25	32	34	30
Sixth	33	31	32	33	31	30	30	29	38	32	34	28	32
Seventh	36	26	27	24	29	27	26	31	28	36	43	43	31

The water entering the White Reservoir has about two thirds of the color of that entering the Nepaug Reservoir.

The Winchester South Reservoir has no visible inlet from the larger part of its drainage area, from which about 60 per cent. of its supply is obtained. The remaining 40 per cent. came into the reservoir for the first year through a small stream leading from a swamp. In subsequent years the swamp was flowed by a reservoir which contained water having a high color, and about 40 per cent. of the supply to the South Reservoir came from this new reservoir. On the whole, the South Reservoir may be regarded as being supplied in the early years by water having a higher color than that supplying the Nepaug Reservoir. The period of detention is longer than at Nepaug, giving a greater length of time for bleaching to take place.

When the filling of a reservoir begins at the beginning of a year, the water in the reservoir after the spring floods has substantially the same color as the inflowing water, and it is only in the latter half of the year that the colors rise owing to the matter extracted from the bottom.

Taking into account the difference in the character of the reservoirs, and especially the color of the inflowing waters, I have prepared a second series of tables, given below, which is intended to represent more nearly than the first the probable color of the water in the Nepaug Reservoir.

SUMMARY OF AVERAGES, REPRESENTING NEPAUG RESERVOIR COLORS.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Av.
First, 1917	35	32	30	30	30	30	36	35	64	70	68	66	46
Second, 1918	56	50	42	34	30	30	34	39	44	49	53	50	43
Third, 1919	44	39	36	32	30	30	29	28	30	33	38	38	34
Fourth, 1920	37	34	32	29	29	28	26	24	24	27	34	34	30
Fifth, 1921	33	32	30	29	27	25	23	21	21	24	29	30	27
Sixth, 1922	29	28	27	27	26	25	22	20	20	23	28	28	25
Seventh, 1923	27	26	25	25	24	23	21	19	18	21	28	27	24

The above table represents the best estimate I can make of the probable color of the water in the Nepaug Reservoir during the first seven years.

It may be of interest to have the records of the Whiting Street Reser-

ESTIMATED COLOR OF WATER IN THE NEPAUG RESERVOIR, BASED UPON OBSERVATIONS OF THE COLOR OF WATER IN THE UNSTRIPPED RESERVOIRS NAMED IN THE TABLES.

Reservoir.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Av.
First Year.													
Borden Brook	30	30	30	30	30	30	34	40	40	55	65	77	..
Holyoke, Whiting Street	46	35	30	30	30	30	35	55	60	65	65	56	..
Holyoke, White	30	30	30	30	30	30	42	75	105	110	85	75	..
Winchester, South	..	..	..	..	..	..	33	50	50	50	58	55	..
Averages	35	32	30	30	30	30	36	55	64	70	68	66	46
Second Year.													
Borden Brook	65	60	50	40	30	30	30	30	30	40	50	50	..
Holyoke, Whiting Street	43	35	30	30	30	30	35	42	52	55	45	45	..
Holyoke, White	65	55	40	30	30	30	42	48	55	52	52	47	..
Winchester, South	52	50	46	36	30	30	30	36	40	50	63	58	..
Averages	56	50	42	34	30	30	34	39	44	49	53	50	43
Third Year.													
Borden Brook	45	40	35	30	30	30	28	26	30	35	43	45	..
Holyoke, Whiting Street	40	32	30	30	30	28	26	23	23	26	32	32	..
Holyoke, White	42	37	32	30	30	30	33	37	41	40	40	39	..
Winchester, South	50	48	46	36	30	30	27	25	25	30	35	35	..
Averages	44	39	36	32	30	30	29	28	30	33	38	38	34
Fourth Year.													
Borden Brook	42	39	34	30	30	30	27	24	27	30	40	40	..
Holyoke, Whiting Street	30	30	29	28	27	26	24	22	23	26	32	32	..
Holyoke, White	40	35	32	30	30	29	28	26	..	..	..	..	..
Winchester, South	35	33	31	29	28	26	24	22	22	24	30	30	..
Averages	37	34	32	29	29	28	26	24	24	27	34	34	30
Fifth Year.													
Borden Brook	40	37	33	30	28	26	24	21	21	26	30	34	..
Holyoke, Whiting Street	30	29	29	29	27	25	23	21	20	24	30	30	..
Winchester, South	30	30	29	28	26	24	22	21	21	23	28	26	..
Averages	33	32	30	29	27	25	23	21	21	24	29	30	27
Sixth Year.													
Borden Brook	34	31	29	28	27	25	22	19	18	22	26	30	..
Holyoke, Whiting Street	29	29	28	28	27	25	23	21	20	24	30	30	..
Winchester, South	25	24	24	25	25	24	22	21	21	23	27	24	..
Averages	29	28	27	27	26	25	22	20	20	23	28	28	25
Seventh Year.													
Borden Brook	30	29	28	27	25	24	22	19	18	20	30	30	..
Holyoke, Whiting Street	29	28	27	26	24	22	20	18	17	21	27	26	..
Winchester, South	22	21	21	22	23	24	22	20	20	23	27	24	..
Averages	27	26	25	25	24	23	21	19	18	21	28	27	24

voir at Holyoke for a long series of years, as this reservoir has a storage per sq. mile of drainage area only one fourth greater than Nepaug, and the color of the inflowing water is about the same at the two reservoirs. The bleaching which takes place at the Whiting Street Reservoir is probably greater than that which can be expected at the Nepaug Reservoir, because that reservoir is much shallower than the Nepaug and has a somewhat longer period of detention, and therefore a better opportunity for bleaching.

OBSERVED COLORS OF WATER AT THE SURFACE OF THE WHITING STREET RESERVOIR AT HOLYOKE, MASS., FOR 25 YEARS FROM THE BEGINNING OF ITS USE.

The Filling began in the fall of 1890.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1, 1891	46	35	9	14	18	22	33	55	58	70	58	46
2, 1892	33	18	14	22	26	26	39	33	52	55	38	33
3, 1893	33	..	14	..	26	..	20	..	24	..	26	..
4, 1894	22	..	24	..	33	..	28	..	42	..	33	..
5, 1895	26	29	..	..	24	30	..	..	26	26	..	33
6, 1896	30	..	34	..	26	..	26	..	30	..	22	..
7, 1897	22	..	18	..	26	..	21	..	22	..	32	..
8, 1898	20	20	11	13	16	23	21	19	26	24	24	18
9, 1899	19	18	9	11	18	24	26	26	39	27	27	..
10, 1900	20	24	18	14	19	16	14	9	18	21	18	18
11, 1901	24	..	18	..	..	13	13	..	11	..	18	..
12, 1902	16	..	19	..	9	..	19	..	..	11	21	..
13, 1903	16	..	..	9	..	..	13	..	..	14	..	..
14, 1904	7	..	..	7	..	..	9	..	..	13	..	..
15, 1905	5	..	..	11	..	..	12	..	..	23	..	..
16, 1906	..	20	..	..	9	..	17	13	..	..	10	..
17, 1907	8	..	3	..	5	..	7	..	11	..	12	..
18, 1908	7	11	3	6	2	11	15	14	5	11	13	11
19, 1909	11	10	10	11	6	11	11	11	12	17	19	33
20, 1910	15	16	11	10	10	9	12	12	12	8	13	11
21, 1911	12	12	3	11	17	21	16	26	20	20	23	20
22, 1912	20	10	5	5	5	8	11	10	10	10	12	13
23, 1913	12	11	11	10	..	6	..	4	..	8	..	10
24, 1914	..	10	..	6	..	2	..	10	..	..	..	10
25, 1915	..	2	..	8	..	10	..	5	..	10	..	..

February 23, 1918.

You have brought to my notice the fact that in the recent consideration of the probable color of filtered water, the question of the difference between maximum and average colors has assumed importance.

At the time of making my previous reports, I did not go into this matter, because I knew that in the case of large reservoirs like the Nepaug there is such a marked degree of uniformity in the color of the water at the dam in different portions of the year that the differences between the average and maximum colors are hardly noticeable, except to the trained eye using scientific apparatus for determining colors.

There are two ways of studying this question. One is by taking directly the results of practical experience. The other is by dealing with the matter in a more theoretical manner. By both methods it can be demonstrated that the large volumes of high colored water thrown into such great reservoirs after storms do not have any marked effect upon the color of the water when it reaches the dam, and still less upon the color of the water after it is filtered, even though chemicals are not used.

The results of practical experience are the most easily understood, and are more likely to be convincing because they do not depend upon any theory or manipulation of figures.

When an unstripped reservoir is first filled, the water acquires after standing for a time a considerable amount of color, chiefly from the vegetable matters which have been flooded, as I have stated in a previous report, but as time goes on the amount of color extracted from the bottom becomes less and less so that after a term of years the unstripped reservoir becomes the same as a stripped reservoir. In regard to coloring matter, this condition is substantially reached in from 6 to 10 years from the time the reservoir is first filled.

After this permanent condition is reached, experience with a stripped reservoir is applicable to an unstripped reservoir, and there should be little or no greater fluctuations of color in the water of the unstripped than of the stripped reservoir.

Average and Maximum Colors at Wachusett Dam. The fluctuations in color which have occurred at the Wachusett Reservoir, which is the only reservoir in New England having a larger capacity than the Nepaug Reservoir, are shown in the following table:

AVERAGE AND MAXIMUM COLORS OF SURFACE WATER AT WACHUSETT DAM.

Year.	Average Color.	Maximum Color.	Excess of Maximum Over Average.
1908	20	29	9
1909	18	24	6
1910	17	28	11
1911	8	10	2
1912	13	17	4
1913	13	16	3
1914	13	18	5
1915	15	17	2
1916	12	13	1
1917	10	11	1
Average for last 7 years.	12	15	3

The Wachusett Reservoir was first completely filled in 1908, and for the first three years seems not to have reached an entirely normal condition. A space has therefore been left under these three years and the averages cover the last seven years.

The average results for the seven years show that the maximum color of the water at the dam was 3 points above the average for the year. In one year of the seven, it was 5 points above. If one third of the color were removed by filtration, the filtered water in the extreme case would be 3 points above the average.

Color Removal in Wachusett Reservoir. There are two principal streams entering the head of the Wachusett Reservoir, one about twice as large as the other. The colors of both streams are recorded. In order to obtain a correct mean for the year, it is necessary to allow double weight to the color of the water of the larger stream and to give the color of the water for each month weight in proportion to the quantity of water flowing into the reservoir in that month. The average colors of the entering water as given in the following table were obtained in this way.

AVERAGE COLORS OF WATER ENTERING WACHUSETT RESERVOIR AND OF SURFACE WATER AT THE WACHUSETT DAM.

Year.	Entering Water.	Surface Water at Dam.	Per Cent. Reduction.
1911	40	8	80
1912	37	13	65
1913	41	13	68
1914	36	13	64
1915	48	15	69
1916	41	12	71
1917	33	10	70
Averages	39.4	12	70

It will be noted that the average color removal due to storage in this reservoir was 70 per cent.

Colors at Dam Little Affected by Occasional High Colors at Inlet. It is a peculiar feature brought out by practical experience with large reservoirs that there may be an abnormally high color of the water at the upper end of such a reservoir and its effect almost entirely disappears before the water reaches the dam. This may be due in part to diffusion as well as to bleaching, but it seems also to be the case that the additional coloring matter brought into the head of a reservoir after storms is less stable and bleaches more rapidly than ordinary colors.

There is a remarkable example of this in the records of the Wachusett Reservoir for July and August, 1915. During these months there was a rainfall representing more than one third of the whole rainfall for the year, and the quantity of water discharged into the reservoir from the drainage area during these two months was 9 240 m.g., a quantity nearly as large as the total capacity of the Nepaug Reservoir and nearly one seventh of the full capacity of the Wachusett Reservoir. This great volume of water had

an average color of 80, fully double the usual color, and yet at the dam the maximum color during the year was only 2 points above the average.

If this great volume of high colored water had moved along without diffusing and mingling with the other water already in the reservoir, and it had bleached only in the same proportion as the ordinary water — that is, 70 per cent. — the color at the dam would have been 24 some time in the latter part of 1916 or early part of 1917, as the average time for the passage of water through this reservoir is about a year and a half. In the last two months of 1916 the color of the water at the dam was only 11, and in the first five months of 1917 it averaged only 9. At no time during 1916 was the color of the water at the dam above 13, showing clearly that the high color of entering water due to floods disappeared before the water reached the dam.

Effect of Phelps Brook on Color of Water — Results of Experience. The suggestion has been made that the water of Phelps Brook, having a higher color than the water of Nepaug River and emptying drectly into the Phelps Brook Basin, may cause a materially higher color of the water drawn from the Phelps Brook Dam for city use than that indicated by considering Nepaug River alone as the feeder of the reservoir.

When this suggestion was originally made at the first conference between the Board of Water Commissioners and the experts, I ventured an off-hand statement that while the effect of Phelps Brook had not been considered in making my estimates of the color of the water at Phelps Brook Dam, I did not believe its inclusion would increase the color more than 1 or 2 points. This view may be given the test of practical experience, because essentially the same unfavorable conditions which are depicted at the Nepaug Reservoir are reproduced in a more extreme way at the Wachusett and Sudbury reservoirs of the Metropolitan Water Works.

The Nepaug Reservoir is depicted as being much the same as if there were two separate basins with a connection between them, one the Nepaug Basin, receiving most of its water from Nepaug River, and the other the separate Phelps Brook Basin, receiving all of the water of Phelps Brook and that of other streams tributary to this basin, and taking from the Nepaug Basin only the additional quantity of water required to meet the needs of the city for water.

Estimates were presented to show that when the water consumption in the city is 15 m.g. daily the average time required for the passage of water through the Phelps Brook Basin when it is full will be 246 days, and that when the water consumption is 30 m.g.d. the corresponding time will be 123 days.

Essentially the conditions depicted exist at the Wachusett and Sudbury reservoirs, with the unfavorable features so greatly exaggerated that their effect upon the color of the water of the Metropolitan Water Works would be very much greater than at the Nepaug Reservoir.

The Wachusett Reservoir may be likened to the Nepaug Basin of the

Nepaug Reservoir. Like that basin, it receives at its upper end the bulk of the water supply. In both cases the water for municipal purposes flows from the basin receiving the bulk of the water into another basin from which the water is drawn for use; that is, the water from the Nepaug Basin flows into the Phelps Brook Basin, and the water from the Wachusett Reservoir into the Sudbury Reservoir. In each case when the first basin is full and there is surplus water, it flows over the spillway of a dam at the lower end of the basin in which the water is first received.

Near the head of the Phelps Brook Basin, Phelps Brook with a drainage area of 2.9 sq. miles discharges a high colored water (average color 42) into the basin. This feature has its counterpart at the head of the south branch of the Sudbury Reservoir, into which the water is discharged from the Wachusett Reservoir. At this place there is a group of small streams discharging into the open channel of the Wachusett Aqueduct from a swampy territory having a drainage area of 7.8 sq. miles. The water from these streams has an average color of 78, nearly twice that of Phelps Brook. Near the head of this branch of the Subdury Reservoir also, there is another stream on which there is a good sized swamp, increasing the drainage area of the swampy stream from 7.8 to 8.5 sq. miles.

The connection between the Nepaug and Phelps Brook basins is a narrow portion of the reservoir. That between the Wachusett and Sudbury reservoirs is an aqueduct. This difference does not seem to have importance under usual conditions, because in both cases the flow of water is always from the basin which receives the water into the one from which it is drawn for use, and the quality of the water does not change in passing from one to the other, except in one unimportant way which will now be noted.

After the water from the Wachusett Reservoir reaches what is known as the Open Channel of the Wachusett Aqueduct, it receives the discharge of water from several swampy streams, and this discharge mingles with the water flowing in the channel and increases the color at its lower end where it discharges into the head of the Sudbury Reservoir. It is clearly immaterial whether these swampy streams which receive their water from a part of the drainage area of the Sudbury Reservoir mingle with the water in this channel or whether they discharge into the reservoir as separate streams, as the effect would be the same in either case.

Between the head of the Sudbury Reservoir and the dam, the conditions for bleaching the water are very much less favorable than in the case of the Phelps Brook Basin. At the latter basin, as already stated, the average time required for the passage of water from its head to the dam will vary from 246 days when the consumption is 15 m.g.d. to 123 days when it is 30 m.g.d.

At the Sudbury Reservoir the average quantity of water drawn through the Wachusett Aqueduct in the last seven years has been 85 m.g.d., and the average discharge into the upper end of the reservoir from the drainage

area about 9 m.g., making a total of 94 m.g.d. The average time required for this water to pass from the head of the reservoir to the dam is about 51 days.

Notwithstanding the unfavorable conditions stated, namely, the high colored water entering the head of the Sudbury Reservoir with the water from the Wachusett Reservoir and the short time for the bleaching of the water before reaching the dam, the average increase in color at the Sudbury Dam over color at the Wachusett Dam is only 2 points. The following table shows the average and maximum color of water at the Wachusett Dam and at the Sudbury Dam.

AVERAGE AND MAXIMUM COLORS OF SURFACE WATER AT WACHUSETT AND SUDBURY DAMS.

Year.	WACHUSETT DAM.		SUDBURY DAM.	
	Average.	Maximum.	Average.	Maximum.
1911	8	10	9	11
1912	13	17	16	25
1913	13	16	15	19
1914	13	18	16	22
1915	15	17	19	24
1916	12	13	14	21
1917	10	11	12	14
Averages	12	15	14	19

The average difference between the average and maximum colors at the Sudbury Dam is 5 points, and the maximum in any year is 9 points.

As the maximum number of 9 points seemed large I examined the detailed records to ascertain its cause, and found that it was due to a cause which would not exist in the case of the Nepaug Reservoir, namely, the shutting off of the flow through the aqueduct from one reservoir to the other.

The Wachusett Aqueduct was shut off all the time from March 13 to April 18, 1912, with the exception of two days. This was a period when the streams were discharging a very large quantity of water, the run-off from the Sudbury drainage area averaging 5.2 m.g. per sq. mile of drainage area. On this basis, the 8.5 sq. miles representing the drainage area of the swampy streams at the head of the Sudbury Reservoir would discharge an average of 44 m.g. per day, which in the 37 days would amount to 1 600 m.g.

The color of the water at the lower end of the open channel during this period averaged 77; hence, a great quantity of very highly colored water was discharged into the upper end of the south branch of the Sudbury Reservoir without dilution, except on two days out of the 37, with the bleached water from the Wachusett Reservoir. During this time the water in the Sudbury Reservoir was about five ft. below full reservoir level.

Immediately after this period, water was discharged from the Wachu-

sett Reservoir into the Sudbury Reservoir in large quantities, so as to furnish not only the supply needed for the Metropolitan District but also to fill the reservoir, with the result that the high colored water was pushed rapidly down to the Sudbury Dam, producing in May the highest average monthly color recorded at that dam in the seven years. The highest color reached in any week was 26, in the latter part of April.

Color of Combined Wachusett and Sudbury Waters. In the foregoing presentation of the effect of the Sudbury Reservoir upon the Wachusett water, I have taken account only of the swamps at the head of the south branch of the Sudbury Reservoir, but there is a drainage area tributary to the north branch which also contains swamps.

The treatment of the question already given is the best one for showing by practical experience that Phelps Brook will have no important effect upon the color of the water at the Phelps Brook Dam, in view of the fact that under very much more unfavorable conditions at the Sudbury Reservoir such conditions do not produce a large increase in color at the Sudbury Dam.

The general problem of the reduction of color by storage in the Wachusett and Sudbury reservoirs may be treated in another way. The color of the water entering the Sudbury Reservoir is not very definitely known, except from the 7.8 sq. miles above referred to, where the color as deduced from 16 observations in the years 1911 to 1915, inclusive, has been determined to be 78, as shown by the following table.

COLORS OF WATER AT THE LOWER END OF THE OPEN CHANNEL WHEN NO WATER WAS FLOWING THROUGH WACHUSETT AQUEDUCT.

Week Ending.	Color.	Week Ending.	Color.
1911: March 21	59	1912: March 19	92
March 28	57	March 26	81
April 4	60	April 2	88
April 18	58	1913: April 15	93
April 25	68	April 22	97
May 2	76	April 29	87
May 9	82	1915: January 26	76
May 16	83	February 23	86
Average	78	Average	78

Before the Sudbury Reservoir was built, samples of water from the stream near the site of the dam were examined monthly by the Massachusetts State Board of Health from 1888 to 1895, inclusive, and the average color by the Nessler standard during these years was 101. Transforming this to the Platinum standard now used, the average color becomes 82.

Since that time many of the swamps on the drainage area have been drained causing a reduction of color, and some swamps as well as much upland have been flooded by the construction of the reservoir. It seems

probable that the color of the water entering the Sudbury Reservoir at the present time averages not far from 60.

The Sudbury Reservoir has a capacity of 7 253 m.g. The drainage area, including the reservoir, is substantially 23 sq. miles, so that the storage per sq. mile is 314 m.g., a very little more than that of the Nepaug Reservoir. In a reservoir of this size the reduction of color, according to the investigations of Ralph H. Stearns[1], should be 48 per cent.; hence, the average color at the dam should be 52 per cent. of 60 = 31.

The average discharge from the Sudbury drainage area is substantially 1 m.g. per sq. mile, or 23 m.g. per day, while the average discharge through the Wachusett Aqueduct was, as already noted, 85 m.g.d. The result of mixing these quantities of water with their respective colors is shown by the following computation:

$$\begin{aligned} 23 \times 31 &= 713 \\ 85 \times 12 &= 1\,020 \\ \hline 108 \times 16 &= 1\,733 \end{aligned}$$

This computation gives an estimated color of the water at the dam of 16, which is 2 points higher than the average observed color.

[1]Jour. N. E. W. W. A., Vol. 30, 1916, page 20.

Discussion.

Karl R. Kennison.* The data which the author has presented clearly show that the reduction of color during the time in which the entering brooks discharged only a relatively insignificant flow into the reservoirs was very much greater than the average reduction of color over longer periods of time. This result would naturally be expected and leads me to emphasize again, as I did in my recent paper on the subject, that it is difficult to isolate the true bleaching effect which is in reality much greater than one would conclude from observations affected by the color of entering brooks.

Robert Spurr Weston.† One thing which ought to be borne in mind when comparing the colors of waters entering reservoirs through their feeders with the colors of waters flowing from reservoirs is that the methods used by chemists for measuring color are not always the same. Most chemists use the so-called standard methods of the American Public Health Association. These provide that the samples shall be passed through filter paper before the color is observed. Filtering removes some of the coarser suspended matter which settles out readily in the reservoir; consequently, if the chemist neglects to filter the samples before determining the color, higher degrees of removal by storage in the reservoir would be indicated. This may be the explanation of the high degree of color removal in the case of one of the reservoirs mentioned by the author.

There is another thought which comes to mind in connection with this rather intricate problem. This is that while we can determine quite accurately the color of the water which leaves the reservoir, we do not know the actual color of the water which enters the reservoir. It is true that we know the colors of the entering brooks, and we can compute a weighted average of the color of the waters of the entering brooks. However, we cannot know accurately the percentage of ground water entering through the sides of the reservoir, and because we cannot measure it, we cannot estimate the amount of color. If the entering ground water is colorless, it dilutes the colored water from the feeders.

Another point which should be considered is that the time of passage of water through the reservoir is dependent more or less upon the shape of the reservoir. The Wachusett Reservoir is almost ideal in shape. The Quinapoxet and Stillwater rivers enter at the upper end and the discharge is at the lower end of the reservoir. This condition obtains also at the new Wanaque Reservoir in New Jersey. The Wanaque River, and all the large feeders, enter at some distance from the dam. Consequently full-time storage is provided for the reduction of color.

We must, thus, consider not only the storage ratio‡ of the reservoir but also its shape, the arrangement of tributaries, and, as stated before, the method of estimating the reduction of color.

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†Of Weston and Sampson, Consulting Engineers, Boston.

‡The storage ratio is the reservoir capacity divided by the mean annual run-off. A storage ratio of 1.0 is equivalent, roughly, to storage for one year.

PROCEEDINGS.

NOVEMBER MEETING.

SPRINGFIELD, MASS.

WEDNESDAY, NOVEMBER 13, 1929.

The November Meeting of the Association was held in connection with an inspection of the new water supply developments of the cities of Springfield and Westfield, Mass.

Meeting in front of the Municipal Building at Springfield, Mass., the party proceeded by automobile to the Granville Dam and Reservoir of the city of Westfield. Thence the route lay via the West Parish Filters of the city of Springfield to the Intake Dam, Power House, Power Tunnel and Surge tank and penstock locations of the Little River Development. Luncheon was served at the Engineer's Camp. In the afternoon Cobble Mountain Dam and Spillway which were under construction were inspected and the Engineer's Laboratory at the camp was visited.

DECEMBER MEETING.

BOSTON CITY CLUB, BOSTON, MASS.

WEDNESDAY, DECEMBER 11, 1929.

President Robert Spurr Weston in the Chair.

THE PRESIDENT. As you know, a committee was appointed following the September convention to take up the question of the diversion of waterworks funds for other municipal purposes. We have had a very good committee at work on this matter this fall. It has held several meetings and is ready to report.

Your President, however, has received, since the adjournment of the committee, a letter from one of our oldest members, Mr. Hathaway of Springfield, which bears on this subject. After consulting with Mr. Taylor, the chairman of the committee, it has been thought best to read this communication so that the committee and the association may have the benefit of Mr. Hathaway's ideas before acting upon this rather important matter.

The letter is addressed to the Committee on Legislation, of the NEW ENGLAND WATER WORKS ASSOCIATION, and to the Members of the Association in Meeting Assembled at Boston, December 11, 1929. The letter follows:

"The following few brief and hastily written opinions and suggestions from an old-time member, who cannot be present with you, are herewith offered for what they may be worth, viz; — for further thought or for the waste basket.

All water works officials are a unit, I think, in their opinion of such legislation and the manner of its being passed by the Legislature, and would like to see some change made in its applications.

The writer thinks that the provision for appropriating water funds by the City Council or similar authorities, as worded in the said Chapter, is a long step or wedge towards future political control, instead of the proper business control. In so thinking he admits he may be a crank on the subject and is willing to let it go at that.

If the said Chapter was amended so that the political provisions should not include municipal utilities or public service enterprises (so-called by high state and federal authorities),— such as water, gas, electric, etc., plants,— which should be self supporting and be administered by properly interested commissions or trustees of the people,— it would appear that such change would be highly desirable for all concerned.

In regard to the revenue funds of such municipal utilities, and the insuring of their proper use for purposes of the utility, only, (as widely recommended by the highest authorities) the Legislature can best accomplish the needed result by passing an act (in negative form) to the effect that such revenues of public service enterprises shall not be appropriated or used for any purpose other than for that enterprise.

This would insure the needed protection of such funds and would avoid the hampering and handicapping of the efforts of those authorities placed in charge of such public service enterprises, in their attempts to administer the affairs of the enterprises on a proper business basis and for the best interests of the people served.

It would seem to me that this would take care of what Mr. Waddell (of the State Accounting Office) had in mind when, at the March, 1929 meeting of the Association the burden of his remarks was that all water works revenues should be held for water works purposes alone.

But the holding agency should, in my opinion, be the agency that administers the affairs of such utility or enterprise, and that is always in close touch with its needs and conditions, and which can best insure a proper and needful separation of such enterprise from the ever-present and always-grasping political influences in every city and town in the state.

Please note enclosed abstracts of opinions from some of the leading authorities of the present time on this matter; and especially what Mr. Nicholas S. Hill, Jr., says on the subject. Is there any state or city official who will call him ignorant or beside the mark when he says, 'What the water works of today needs most, however, is freedom from partisan politics and independent administration.' '. . . isolate the water department and treat it as a utility.' '. . . separate entity . . . .' 'All water revenues . . . should be . . . applied by IT to the needs of that department.' What does he mean by 'it'? Does he refer to city councils or other political bodies?

A perusal of the several reports to the Legislature of the Special Commission Established to Investigate Municipal Expenditures and Undertakings, etc., as well as the report of the Department of Corporations and Taxation under date of December 1, 1927, shows that the corporation and taxation ideas are the dominant ones, as they properly should be from such bodies. At the same time we find much in connection with the subject of providing that every utility should receive all of its just revenues (for city uses as well as other consumers) and also pay all of its just

expenses (including taxes on the utility property within the city), in the same manner and to the same extent that is expected of any privately-owned utility; and to this extent we all are in sympathy with their endeavors.

But:— I am wondering why the following procedure should not be adopted and established by the Legislature of Massachusetts, in reference to all municipally-owned utilities, in like manner as is provided for the privately-owned utilities in practically all of the states of this country, viz;—

(a) The placing of all municipally-owned utilities (or public service enterprises) under the reasonable control and jurisdiction of the Massachusetts Public Utility Commission, as to proper and adequate rates and also as to uniform and adequate accounting systems, including the holding of all revenues of such self-supporting municipal utilities and the use of same for purposes of such utilities.

(b) The control and jurisdiction of all city and town governmental departments (not municipal utilities) under the Department of Corporations and Taxation (with its natural divisions, including the state accounting division), as to my mind was the original intention when such state department and its divisions was first contemplated and established; not the extension of its functions into the utility field in the manner of recent years. The two dominant words in the title of this department, —'Corporations' and 'Taxations',— indicate to my mind its natural and proper functions. Of course there are officials who will not agree to this, I expect, but I am absolutely sure that if such functions were divided as suggested, the results would fully justify such division and separation of jurisdiction.

Many years of observation and experience have convinced me of the wisdom of some such procedure, and the enacting of corrective legislation whenever those bodies of the Massachusetts Legislature can be convinced of the existing need.

With due apology for hastily putting the foregoing thoughts in type, I am submitting the foregoing, as before stated, for either the brain basket or the ever useful waste basket.

Respectfully yours,

A. R. HATHAWAY,
Water Registrar of Springfield."

I think, having read this letter, the meeting is ready for the report of our special committee.

STEPHEN H. TAYLOR.*

To the Officers and Members of the New England Water Works Association:

Gentlemen: Your committee to consider legislation regarding the diversion of water works funds for other purposes has held several meetings, and a conference with the Director of Accounts of the State of Massachusetts.

It appears that the bill which was presented last spring to prevent such diversion, and which appears on page 336 of Volume 43 No. 3 of the JOURNAL, is still under consideration by the committee of the legislature. It also appears that there is very little possibility of such a bill being enacted. The best bill which it seems possible to obtain is as follows:

Section 1. Chapter 44 of the General Laws is hereby amended by adding the following new sections:—

Section 2a. All water department revenue shall be held and appropriated only for maintenance, operation and improvement of water works plants, for the retirement of water works bonds, and for the payments of interest upon such bonds.

Section 2b. All water departments, as an operating expense, may, when voted by the town, pay to the owning municipality a sum of money in lieu of taxes based on plant values, but not to exceed 3 per cent. of said value. All municipalities shall pay their water departments fair annual charges for fire protection, and all municipalities shall pay their water departments for water used for other municipal purposes at the rates charged to other consumers, which rates, including the charge for fire protection, shall be sufficient to meet the operating costs of the department. In fixing the sum to be paid in lieu of taxes, and the charge for fire protection, the same basis of plant valuations shall be used, and for this purpose the water departments shall carry in their annual reports a statement of said plant values. Should any questions arise as to the unreasonableness of the sums charged in lieu of taxes, or as to the charges for fire protection, appeal may be made to the Department of Public Utilities, whose decision in the premises shall be final.

Inasmuch as this second bill is a considerable variation from the original bill suggested, your committee feels that this matter should be resubmitted to the Association without recommendation.

Respectfully submitted,

STEPHEN H. TAYLOR
FRANK A. BARBOUR
JOHN F. SULLIVAN
CHARLES W. SHERMAN
GEORGE A. KING.

*Superintendent of Water Works, New Bedford, Mass.

Upon motion of David A. Heffernan* duly seconded, and after discussion by Messrs. Patrick Gear and John F. Sullivan, it was voted unanimously to take no action on the report of the Committee.

The Secretary announced the election on December 11, 1929 of the following to membership in the Association: *Members:* John B. Belknap, Framingham, Mass.; Elisha J. Dionne, Salem, Mass.; Howard C. Mandell, New Bedford, Mass.; David E. Moulton, Portland, Me.

Associates: Chase Brass & Copper Co., Inc., Waterbury, Conn.

The Secretary stated that in addition to these, at a prior meeting, Sir Alexander Houston, Director of Water Examination, Metropolitan Water Board, London, England, was elected to Honorary membership.

A paper on "Changes in Power and Pumping at Newport, Rhode Island," was read by Harold Watson, Newport Water Works, Newport, Rhode Island.

A paper on "Marshfield Pumping Station," prepared by Fred O. Stevens, Consulting Engineer of Symonds & Stevens, Boston, was read by Henry A. Symonds.

Messrs. Donald W. Foster and Henry T. Gidley participated in the discussion.

(*Adjourned.*)

*Superintendent of Water Works, Milton, Mass.

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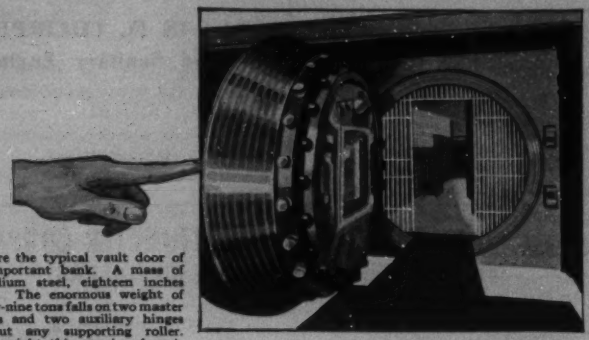

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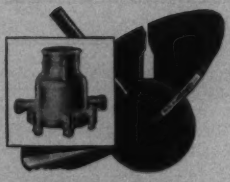
Increase the revenue of your department by installing Hersey Water Meters. For thirty years they have been the criterion of accuracy.



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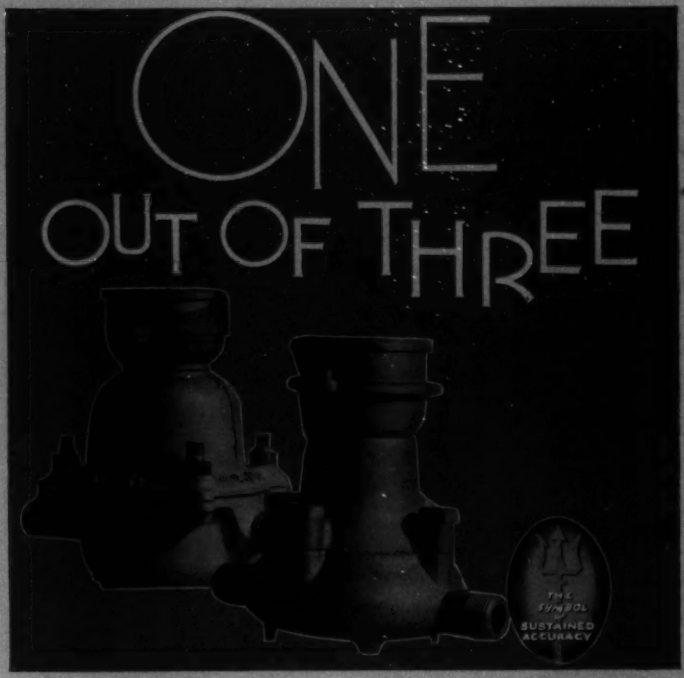

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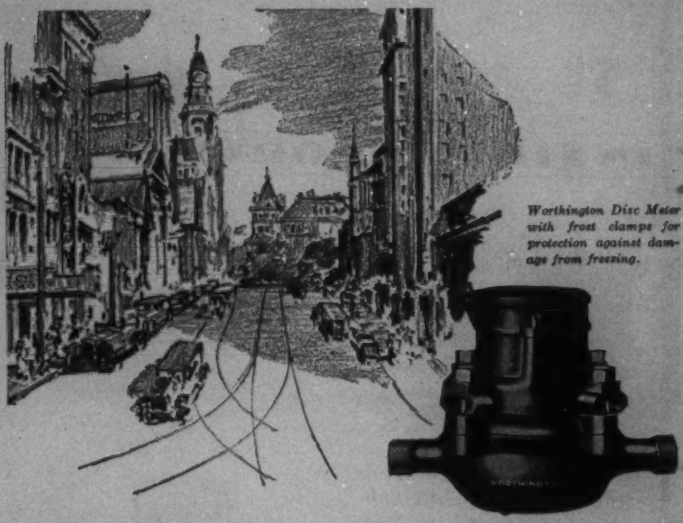

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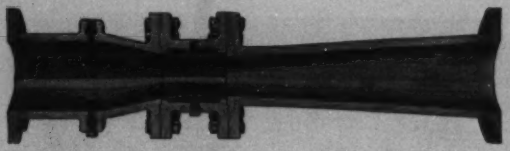

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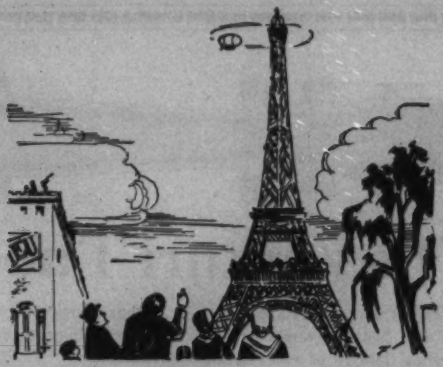

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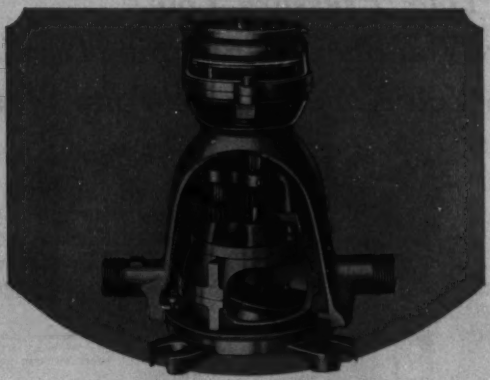

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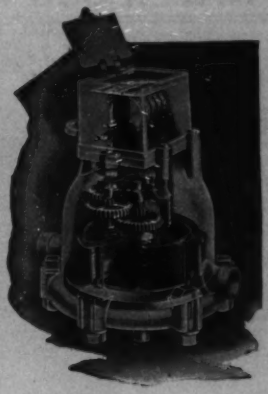

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At least we think so, and that one is - - -

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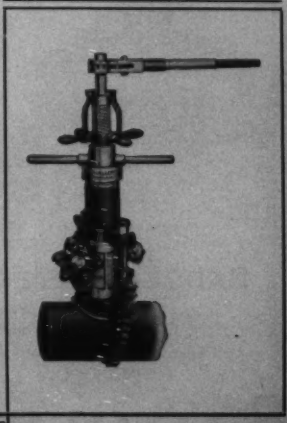

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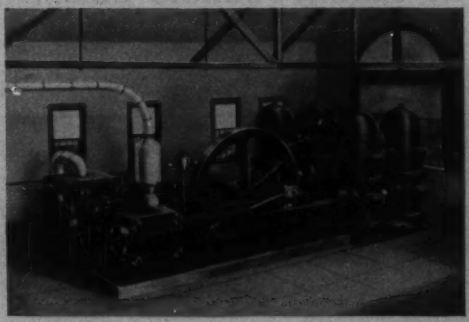
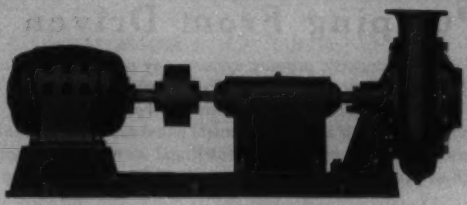


Murray High Duty Crank and Fly Wheel Pumping Engine, Opposed Type

STARKWEATHER & BROADHURST, INC.,
79 MILK STREET, BOSTON

will be glad to show you the superior design and excellent workmanship of the new 3 M. G. D. Murray Pump in the Arlington Pumping Station of the Metropolitan District Commission. Exceptional operating results are being obtained as shown by the official duty test which exceeded the guaranty by a substantial amount.

PLEASE SEND US YOUR SPECIFICATIONS AND CALLS FOR BIDS



Fairbanks-Morse Horizontal Trash Pump direct-connected to Fairbanks-Morse Ball-Bearing Motor

Now a great advance in sewage pumping

For the first time a pump has been designed that will handle fluids containing the fibrous and stringy matter found in sewage — without clogging, without preliminary screening, and without the excessive power consumption that characterizes the less satisfactory open impeller type of pump.

The secret of this pump's success lies in the design of the simple two-blade impeller. The blades of the impeller have well-rounded entering ends and are well filleted with the shrouds or sides. Thus a rag or other trash does not find sharp projections on which to catch and cause clogging. Since the impeller is the enclosed type, foreign matter, in passing through, does not come into contact with stationary side plates, but is promptly discharged through one of the large ports into the pump case. In this way power is conserved and efficiency increased.

This pump was designed by Mr. A. B. Wood who has been serving the city of New Orleans and other municipalities in the capacity of consulting engineer. It was originated by Mr. Wood to cope with the very unusual sewage problems found in New Orleans and met with immediate success.

Fairbanks-Morse Trash Pumps are made in two types, horizontal and vertical. They are ruggedly built to cope with severe service and at the same time they possess such refinements as ball bearings, smoothed fluid passages, and other marks of quality construction.

Ask for bulletins giving complete details.

FAIRBANKS, MORSE & CO., Chicago

28 branches in principal cities at your service.

FAIRBANKS-MORSE

PUMPS · DIESEL ENGINES · MOTORS

DE LAVAL CENTRIFUGAL PUMPS
For Pumping From Driven Wells

BY the use of our automatic priming system, any number of such wells can be pumped by our De Laval Centrifugal Pumps even when in the dry season a considerable suction lift exists. The illustration below shows two motor driven vacuum priming pumps with automatic control panel and vacuum tank serving two sand chambers from which multistage centrifugal water works pumps take their suction. Each sand chamber takes its supply from fifty—2½" driven wells.

The reciprocating pump in the foreground was already in the plant and is now connected as a standby only.

This system continuously removes all air entering with the water and the station becomes fully automatic in operation without any danger of pumps starting up without priming or losing their priming due to unusual air leakage.

TURBINE EQUIPMENT CO. OF NEW ENGLAND

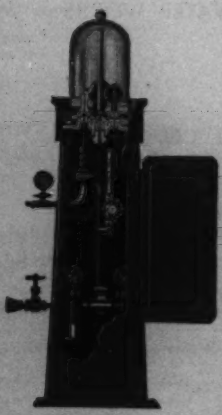
80 Federal St., Boston, Mass. **Phone LIBerty 5993**

Engineers and Contractors for complete De Laval Waterworks Pumping Equipment

Write us for full details and specifications.

IN THE HEALTHY CITIES

Chlorination *of* Drinking Water *is* Continuous



W&T Vacuum Type MSV Solution Feed Chlorinator Rugged—Reliable—Accurate

STATISTICS show that the healthy cities always have low typhoid fever rates. Their health officers know that a safe water means low typhoid. They also know that to assure a safe water supply at all times CHLORINATION MUST BE CONTINUOUS.

THAT'S WHY they insist on strict chlorination control—duplicate chlorinators, careful operating records and regular chemical and bacterial analysis of raw and chlorinated water.

THAT'S WHY over 7,000 W&T chlorinators have been specified for installation in more than 3,500 cities and towns in North America.

THAT'S WHY practically all large American cities are installing duplicate chlorinators as a safe-guard against any possibility of interruptions in chlorination.

Is Your Chlorinating Equipment in Duplicate?

OUR STAFF OF TECHNICAL EXPERTS WILL BE GLAD TO HELP YOU SOLVE YOUR CHLORINATION PROBLEMS

"The only safe water is a sterlized water"

WALLACE & TIERNAN

COMPANY, INCORPORATED

Manufacturers of Chlorine Control Apparatus

NEWARK , NEW JERSEY

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FILTER ALUM

FOR NEW ENGLAND WATER WORKS

MERRIMAC CHEMICAL COMPANY

148 STATE ST. BOSTON

MANUFACTURERS OF FILTER ALUM
SINCE 1886

CARE AND PRECISION
In Smith Valve Making

IN EVERY STAGE of manufacture, Smith Valves are made with extreme care. They have a passageway at least one-eighth of an inch larger in diameter than the connecting pipe. They are made with double discs and parallel seats. Their wedging mechanism is so designed as to force their discs laterally to their seats, after they have completely covered their ports. It is inoperative in any other position.

SMITH WATER WORKS SPECIALTIES & SUPPLIES A.P.S. 1928

THE A.P.SMITH MFG.CO. *East Orange, N.J.*

PRECALKED JOINT PIPE

CAST IRON PIPE

Bell and Spigot—Sand Cast—Modern Weights

Sizes: 1¼ through 12 inches. Lengths to 16 feet

Boston stocks. Furnished with or without Precalked Joints

McWane Cast Iron Pipe Company

Eastern Office: 123 South Broad Street Philadelphia

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General Offices: BIRMINGHAM, ALA.
Foundries: BIRMINGHAM, ALA., PROVO, UTAH

Main's Hotcoating for the inside of standpipes and water tanks, will stop all pitting and corroding, and is guaranteed for seven years.

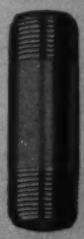
Also

Main's Coverall Salt Air Paint, for the outside of standpipes and water tanks, guaranteed for four years.

M. B. MAIN **Box 189, Somers Point, N. J.**

WARE

RED BRASS NIPPLES



Standard and Extra Heavy
85% Copper Content Guaranteed

Diameters from 3/8" to 4" inclusive.
In stock, ready for 24-hour shipment.

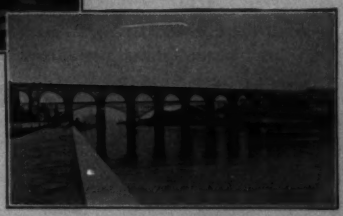
Order through your Jobber, or write us direct for name of nearest distributor.

WARE COUPLING & NIPPLE CO.
WARE, MASS., U. S. A.

Four Generations Have Passed

since the Croton Aqueduct was built . . . .

Yet the wrought iron pipe is still good for generations more!



Away back in the 60's, before the Civil War, a 90-inch wrought iron pipe was installed on High Bridge to carry water from the Croton Aqueduct, across the Harlem River, to New York.

In 1925, when plans for altering High Bridge were being discussed, the question arose whether the big water main was in a condition to be worth saving.

"Good for twenty years," reported the engineers after careful inspection. "Capable of being made to last another sixty years if a protective coating is applied to the inside."

Not a unique but a noteworthy example of the sterling qualities of genuine wrought iron pipe, in water works economy.

Genuine wrought iron is the material from which Byers Pipe has always been made. All the virtues for which Byers Pipe has been known to four generations are built into every length turned out by the Byers mills. The bright Spiral Stripe, which is the Byers mark, is an assurance of lasting service.

A. M. BYERS COMPANY
Established 1864
PITTSBURGH, PA.
Distributors in all Jobbing Centers

the *Spiral Stripe*
protects you against
mistakes and substitution

BYERS PIPE

GENUINE WROUGHT IRON

PIERCE-PERRY CO.

SUCCESSORS TO
GEORGE E. GILCHRIST CO.

JOBBERS OF
Heating and Plumbing Supplies
Steel, Wrought Iron and Brass Pipe
Water Works Materials

DISTRIBUTORS OF
Hoffman Valves and Controlled Heat Equipment

236 Congress Street, Boston.

We Carry in BOSTON STOCK for Immediate Shipment
CAST IRON BELL AND SPIGOT
WATER PIPE AND FITTINGS
FLANGED PIPE in full and short lengths
WROUGHT PIPE
FRED A. HOUDLETTE & SON
(Incorporated)
40 Central Street, Boston, Mass.
Quotations furnished promptly for shipment from Foundry

CEMENT LINED SERVICE PIPE
With Specially Adapted
Lead-lined Fittings
Also Curb Cocks which eliminate Iron to Brass Corrosion both inside and out.
CEMENT LINED PIPE CO.
LYNN, MASS.

NOTICE:
Water-Works Contractors and Supply Houses!
Your card may be inserted here at a rate of $12 per year.

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Manufacturers of and Dealers in
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Service and Valve Boxes
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FIRE HYDRANTS

For Standard and High Pressure Service

Mathews Hydrants are simple in construction; hence durable, easily repaired, and maintained at low cost.

A real Frost Case makes Mathews Hydrants completely frost proof, and with an easily installed

Extension Section

makes the Mathews readily adaptable to new grades and conditions.

Water Works Gate Valves
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CAST IRON PIPE FITTINGS

"Sand-Spun" centrifugally cast pipe
Cast in refractory molds
No chill—Standard bell and beaded spigot

R. D. WOOD & CO.

PHILADELPHIA, PA.

Guarding a City's Welfare

WATER supply and fire protection equipment *must* be thoroughly dependable. Only apparatus of the highest possible grade, meeting the most rigid requirements, can be used.

The wide use of Kennedy Valves and Fire Hydrants by villages, towns and cities throughout the country is therefore the strongest possible proof of their general acceptance as being reliable and efficient. Both large and small municipalities by the score are safely depending on Kennedy products for the control of water supply and fire protection systems.

The big Kennedy line of thousands of different types and sizes of valves, pipe fittings and fire hydrants includes every valve size and method of control for large pipe line operation. Send for the Kennedy Catalog to learn the distinctive features and advantages of Kennedy products.

THE KENNEDY VALVE MFG. CO.
Elmira, N. Y.

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KENNEDY

VALVES-PIPE FITTINGS-FIRE HYDRANTS

Automatic Pressure Control Valves
Feed Water Filters
Portable Fire Hydrant Heads
Hydraulic Engines
Hydraulic Booster Pumps

ROSS VALVE MFG. CO., INC. TROY, N. Y.
ESTABLISHED 1879

Health and Protection First

Water delivered through dirty pipes may be a MENACE.

Incrusted water pipes mean inefficiency and loss of Fire Protection.

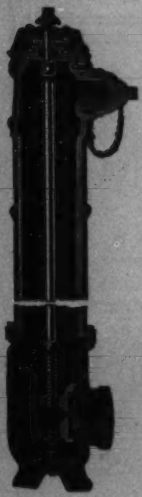
We Guarantee the Results of Our Method of Cleaning.

WRITE US.

National Water Main Cleaning Co.

50 Church Street New York City

A Classified Directory
of Advertisements is arranged for your convenience in the back of this Journal.



LUDLOW VALVE MFG. CO.

MANUFACTURERS OF

VALVES and FIRE HYDRANTS

This hydrant is anti-freezing, because when the drainage is good no water is left in it to freeze.

The drip is directly in the bottom of the hydrant and drains perfectly. It is protected by its valve, which never leaves its socket and cannot be clogged.

DOUBLE AND SINGLE GATE **VALVES,**

ALSO CHECK **VALVES,**

FOOT **VALVES.**

FIRE HYDRANTS.

YARD, WASH, AND FLUSH HYDRANTS.

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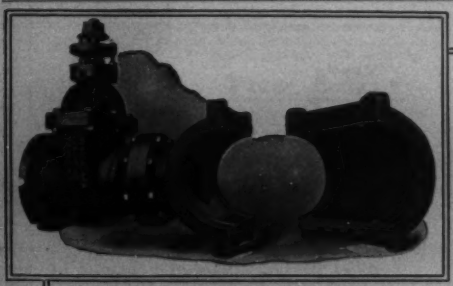

Rensselaer Tapping Sleeves

were brought out to meet a growing demand for a "BETTER" Tapping Sleeve. They were designed to suit conditions met in actual practice.

They can be used with all standard makes of Tapping Machines.

POINTS OF SUPERIORITY

Have two lead rings.

Require less lead for calking.

Iron washers not required.

Bolting flanges are made full length of sleeve, giving great strength.

Have greater thickness of hubs on ends.

Easier to center on pipe before pouring lead.

Cost less to install.

Book No. 11 gives full information.

Ask for prices.

CHARLES L. BROWN
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RENSSELAER VALVE COMPANY, TROY, N.Y.

THE CHAPMAN VALVE MANUFACTURING COMPANY

Manufacturers of

Gate Valves Drip Valves

Gate Fire Hydrants

Corporation Cocks Curb Cocks

Anderson Couplings

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Indian Orchard, Mass.

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Type of Eddy Hydrant Popularly Used

More Than Sixty Years of Experience Goes Into All

EDDY

Hydrants and Valves

BUILT TO MEET EVERY EXACTING REQUIREMENT OF WATER-WORKS SERVICE

Practical water-works men instantly recognize the superior features of Eddy products. For instance, with the hydrant.

A damaged valve can be replaced in a few minutes — Water hammer is avoided by the valve closing against the pressure and the use of the cut-off under the valve, which gradually closes it —
Stems cannot be bent in closing the hydrant.
Nothing can lodge on the valve seat to prevent closing of the valve —
The Drip Rod can be removed without interfering with the hydrant in any manner —
The position of the stem of the hydrant indicates accurately the position of the valve —
Whatever can pass the valve opening will pass the standpipe —
No frost case necessary —
All of these points are explained thoroughly in our catalogue, which will pay you to study.

The Eddy Valve, Too

Has its distinctive and individual features. The double disk gates are free to adjust themselves in different positions every time the valve is closed, thereby keeping smooth and tight faces. And two bronze hooks on the ball loosely engage with the gates to prevent them from spreading at the top. The center bearing gates are forced to their seats with equal pressure at all points. There is a good deal more worth knowing about Eddy Valves. Further details will be sent for the asking.

Other Eddy Products

The Eddy line of water-works products also includes horizontal and vertical check valves, foot valves, hydraulically operated valves, indicator posts, etc.
All goods made by the Eddy Valve Company are manufactured exclusively at Waterford, New York.

WRITE FOR CATALOGUE

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WATERFORD, N. Y., U. S. A.

EMAUS PIPE FOUNDRY,
DONALDSON IRON CO.,

MANUFACTURERS
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CAST IRON PIPE

...AND...

Special Castings for Water and Gas.
Also Flange Pipe, Street Castings,
Manhole Heads and Covers, etc.

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J. M. GILBERT, Secretary.

EMAUS,
LEHIGH COUNTY, PA.

CALDWELL "LEAKFINDR"

Listening for leak at hydrant

Locating leak in the ground

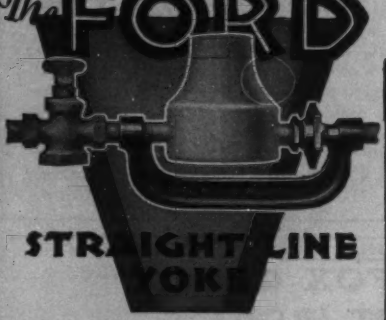
Pronounced by Leading Water Works Superintendents the Best Instrument for the purpose on the market.

Manufactured and Sold by

GEO. A. CALDWELL CO. - - MATTAPAN, MASS.

No. 1 CALDWELL CURB BOX

The FORD



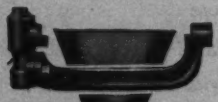
STRAIGHT LINE YOKE

THE FORD Yoke is entirely *different in principle and operation* from any other meter holding device. Piping is held in *absolutely rigid alignment* and water-tight joints are made by *expansion from within* against rubber gaskets in fixed ports. In that principle lies *the undoubted superiority* of the Ford Yoke in all of its various types. The Straight Line Yoke is especially intended for setting water meters in straight service pipes whether in the cellar or in the meter box.

Expansion Connection

Every Ford Yoke includes the Ford Expansion Connection. This is an all bronze connection which is screwed onto the meter spud with a wrench. Meter is then dropped into the yoke between the gaskets and *turning the large hand wheel expands the connection outward* against the gaskets. Meter may be set or removed *without tools* even through a small, neat meter box opening.

The Angle Yoke



Here is another adaptation of the Ford Yoke and Expansion Connection principle. *Where the inlet is vertical and outlet horizontal*, this Angle Yoke should be used. It is made both plain or with stop valve as shown or with bleeder valve, and may be had with or without union. All of the inherent advantages of the Ford Yoke are obtained in any style of setting.

Ask for Bulletins

WATER METER SETTING & TESTING EQUIPMENT

THE FORD METER BOX CO.

WABASH, INDIANA

12 ADVANTAGES

1. *Meter may be installed or removed from the line in a few seconds at any time.*
2. *Costs but little, if any more than the meter couplings and pipe fittings it eliminates. Its cost is often saved in changing the meter once.*
3. *Pipe is maintained in perfect spacing and alignment whether meter is in or out. . . Removal of meter does not move piping; no danger of causing leaks in old piping.*
4. *Meter is relieved of all piping strains.*
5. *Relieves troubles of wrong gasket space and different lengths of meters.*
6. *By making meters more readily available for removal and replacement it tends to make them better cared for and hence more accurate.*
7. *When meter is removed, it is difficult for customer to steal water because he cannot bridge across Yoke.*
8. *Yoke serves as a spacer, giving correct spacing and alignment. Meter may be set in a few seconds any time later. No necessity for pieces of pipe to be used as spacers and replaced with meter. Plumbing work on the outlet cannot destroy spacing or alignment, or put a strain on the meter.*
9. *The Expansion Connection is the only moving part of the Yoke. It is all bronze, and is removed with the meter. When the meter is out, there are no exposed threads to become corroded and fouled as is the case with ordinary couplings.*
10. *Yoke makes it easier to seal meters in line.*
11. *Permits the use of smaller and neater meter box lids.*
12. *For a few cents additional Yoke may be had with test or drain valve at outlet. Dead meters may be easily detected.*

Corrosion of Iron and Steel Water Pipes

Information on this subject is desired by the Committee recently appointed by the Association "to Collect and Correlate Information Concerning the Corrosion of Iron and Steel Pipes and Standpipes." Members are urged to send data relating to the characteristics of the metal, the soil, the water and the protective coatings and to the history and condition of such supply mains (not service pipes) to the undersigned for the use of the Committee.

CALEB MILLS SAVILLE, *Chairman.*
1026 Main Street, Hartford, Conn.

NICHOLAS ENGEL

JOHN FOX & CO.

CAST IRON

WATER & GAS PIPES

FLANGE PIPE

Special Castings, Fire Hydrants, Valves

General Foundry and Machine Work

WOOLWORTH BUILDING 233 BROADWAY

NEW YORK CITY

HIGHEST AWARD, GOLD MEDAL,
ST. LOUIS EXPOSITION, 1904

Over 100 Water Departments

use

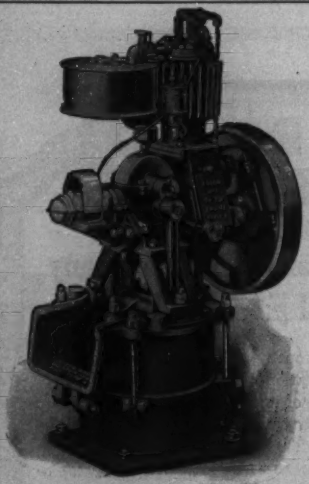
LEAD-LINED IRON and TIN-LINED PIPES

for their service connections

MANUFACTURED BY

Lead Lined Iron Pipe Company

Wakefield Mass.



STYLE "B" ENGINE – STYLE "A" NO. 3 PUMP
Furnished on Hand Skid or 4-wheel Truck

"On Top" Trench Pump Unit

EDSON

DIAPHRAGM
PUMP SPECIALTIES

Hand and Power Outfits

Try one of our Gasoline Two-Pump
EMERGENCY UNITS

Insist on GENUINE EDSON Pumps,
Suction Hose, Diaphragm
with Bead, etc.

New Catalogue on application

Edson Manufacturing Corp.
49 D Street South Boston, Mass.

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201 DEVONSHIRE ST., BOSTON, MASS.
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CAST IRON PIPE

Bell and Spigot Flanged Pipe
Special Castings
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Works, Phillipsburg, N. J.

LARGE STOCK ENABLES US TO MAKE QUICK SHIPMENTS

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Special Castings, Fire Hydrants, Valves

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NEW YORK CITY

HIGHEST AWARD, GOLD MEDAL, ST. LOUIS EXPOSITION, 1904

Over 100 Water Departments

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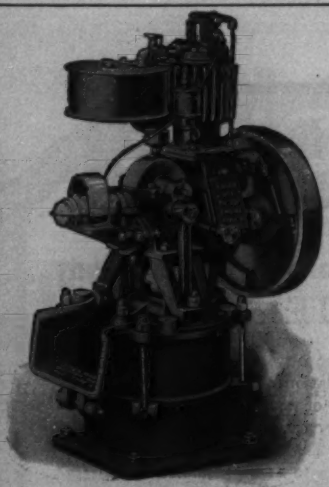
LEAD-LINED IRON and TIN-LINED PIPES

for their service connections

MANUFACTURED BY

Lead Lined Iron Pipe Company

Wakefield ——— Mass.



STYLE "D" ENGINE – STYLE "A" NO. 3 PUMP
Furnished on Hand Skid or 4-wheel Truck

"On Top" Trench Pump Unit

EDSON

DIAPHRAGM
PUMP SPECIALTIES

Hand and Power Outfits

Try one of our Gasoline Two-Pump
EMERGENCY UNITS

Insist on GENUINE EDSON Pumps,
Suction Hose, Diaphragm
with Bead, etc.

New Catalogue on application

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Warren Foundry and Pipe Co.

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Bell and Spigot Flanged Pipe
Special Castings
Flexible Joint Pipe Cylinders

Water Gas Sewers Culverts

Works, Phillipsburg, N. J.
LARGE STOCK ENABLES US TO MAKE QUICK SHIPMENTS

LEADITE

Philadelphia Suburban Water Company —*uses* LEADITE *exclusively.*

THIS well-known Water Company, one of the C. H. Geist properties, supplies a population of about 315,000 persons through approximately 900 miles of water mains.

It is a significant fact that they have USED LEADITE EXCLUSIVELY on approximately 230 miles of their water mains laid in the last 4½ years (sizes up to 24 in. inclusive, and pressures averaging 60 lbs. per sq. in. — with maximum considerably above that figure). In fact, even prior to 1925, this Company used LEADITE extensively.

The daily per capita consumption of water is slightly under 60 gallons, which includes Domestic, Commercial and Industrial users — also fire, flushing and municipal purposes. This figure also includes all losses by leakage. These figures are excellent proof of tightness of pipe lines.

Mr. Carleton E. Davis* is Manager of the Philadelphia Suburban Water Company.

*Mr. Davis is a Past President of both the AMERICAN WATER WORKS ASSOCIATION and the NEW ENGLAND WATER WORKS ASSOCIATION — also former Chief Engineer of PHILADELPHIA BUREAU OF WATER for 11 years.

The Pioneer Self-Caulking Material for C. I. Pipe
Tested and used for over 30 years.
Saves at least 75%

The LEADITE COMPANY — LAND TITLE BLDG.
Philadelphia, Pa.

No Caulking

National-Boston Lead Co.

800 Albany St., Boston

Agents for

The Celebrated "ULCO"

LEAD WOOL

(Every Atom Pure Lead)

For calking pipe joints under the most difficult conditions.

For overhead joints, or in wet places where the use of molten lead is not only impracticable but dangerous — **LEAD WOOL** may be used to advantage.

It makes an absolutely tight joint which will withstand the highest pressure, yet be sufficiently elastic to allow considerable sagging or settling of the pipe without danger of a leak.

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Manufacturers of

Lead Pipe, Tin Lined Lead Pipe, Pure Block-Tin Pipe, Solder, White Lead and Red Lead.

HIGHEST QUALITY SOFT BRANDS

PIG LEAD

Joints that are Stress and Vibration Proof

Unusual situations often met in laying bell and spigot pipe — lines over bridges or railroad crossings — lines to be lowered to grade — are successfully met when the joints are made with Hydro-Tite.

Easy to Prepare

The 8-in. line pictured above is slung across a pond with cables — a span of more than fifty feet.

Every test shows that Hydro-Tite joints will remain perfectly tight when subjected to severe vibration or deflection. If you have never used Hydro-Tite let us tell you more about it. Requires no caulking — 19 years of proven dependability — a real 75% saving and an ever-increasing list of satisfied users.

Write for literature and further information.

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296 Boylston St.

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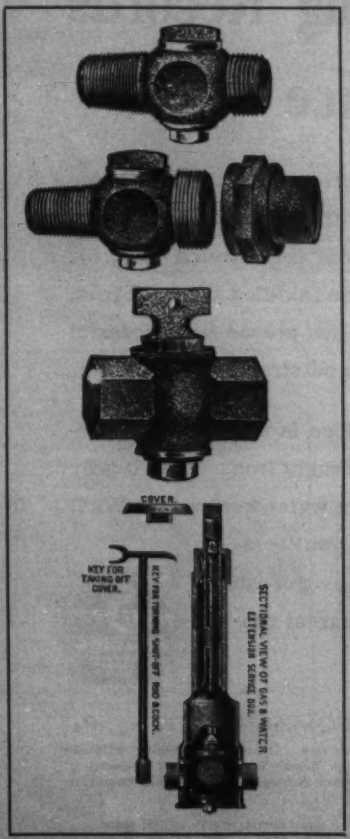
7 So. Dearborn St.

HYDRO-TITE

REG. U. S. PAT. OFF.

The Modern Joint Material

"The Goods That Please"



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We have them to meet every requirement

ORIGINAL

"Hays-Erie"

Extension Service Boxes of proven advantages

Let us send at our risk, on 30 days' trial, a

Payne's Patent Tapping Machine

which is recognized to be the most easily operated owing to the few working parts.

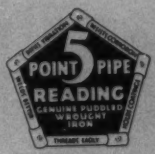
Hays Mfg. Co., ERIE PENNSYLVANIA

Established 1869

Age-Long Records of Service

When you ask, "How long does Genuine Puddled Wrought Iron Pipe endure?", you can refer to records that stretch back for centuries. Genuine Puddled Wrought Iron, through the ages, has proved its successful resistance to rust and strain.

Reading 5-Point Pipe is the original, time-tested, puddled wrought iron. That is why it is an ideal pipe for water works use. We'll be glad to give you complete information — get in touch with our nearest representative today.



READING IRON COMPANY, Reading, Pa.

Atlanta Buffalo Detroit New York St. Louis Fort Worth Baltimore
Chicago Houston Pittsburgh Tulsa Seattle Boston Cincinnati
Los Angeles Cleveland San Francisco Philadelphia New Orleans Kansas City

GENUINE PUDDLED WROUGHT IRON
READING PIPE
DIAMETERS RANGING FROM ¼ TO 30 INCHES

GOLDEN-ANDERSON

Patent Automatic Cushioned Controlling Altitude Valves

We have enlightened many a water user in municipalities, in industrial plants and on railroads, as to the adaptability of these Golden-Anderson Valves, and as to their function of SAVING, and of eliminating troubles.

For automatically maintaining Uniform Stage of Water in Tank, Reservoir or Standpipes. Doing away with the annoyance of Freezing and Float Fixtures inside or outside of Tanks.

"Three Ways of Closing These Valves":
1st —Automatically, by water.
2nd—By Electricity, if desired.
3rd—By Hand

May also be arranged to automatically close when a break occurs in the mains. When necessary they may be so connected as to "work both ways" on a single line of pipe. No valves or fixtures inside or outside.

Sizes to 24 in.

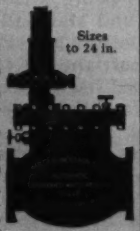
Remember!

"HOSTS OF REFERENCES"
Valves cushioned at all times by air and water
No water hammer or bursting mains

"Made with stop starter attachment for centrifugal pumps"

GOLDEN-ANDERSON
Pat. Automatic Cushioned Water Pressure Regulating Valves

1. Maintain a constant reduced pressure regardless of fluctuations on high pressure side.
2. Perfectly Cushioned by water and air. No metal-to-metal seats.
3. The best valve made for maintaining a constant low pressure where consumption is continuous.
4. Operates quickly or slowly as required — No attention necessary.
5. Positively no hammering or sticking.



Sizes to 24 in.

GOLDEN-ANDERSON
Patent Automatic Cushioned Controlling Float Valves

They carry a constant water level in feed water heaters by perfectly controlling the flow of makeup water.

Operated by protected enclosed copper float.

Cushioned by both air and water.

Operate without hammering, sticking or chattering. No metal-to-metal seats. Made angle or straightway.

Sizes 1 in. to 24 in.

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Pat. Automatic Cushioned Water Float Valves

1. Automatically Maintain Uniform Water Levels in Tanks, Standpipes, etc.
2. Instantly Adjusted to Operate Quickly or Slowly.
3. Floats Swivel to any Angle — Most Satisfactory Float Valves Known.
4. No Metal-to-Metal Seats — No Water Hammer or Shock.
5. Cushioned by Water and Air.

Angle or Globe

Sizes to 24 in.

GOLDEN-ANDERSON
Patent Automatic Double Cushioned Check Valve

Sizes to 24 in. Angle or Globe

Automatically prevents reverse flow of pressure. Perfectly cushioned to prevent shock or hammer. Especially adapted for water works to prevent disastrous reverse flow of pressure due to pumps stopping. Arranged so that quick or slow operating may be obtained.

Golden-Anderson Valve Specialty Co., 1325 Fulton Bldg., Pittsburgh, Pa.

Biggs Electrically Welded Steel Pipe is Manufactured Under Procedure Control, Insuring a *Uniform* Product

This illustration shows a Biggs automatically welded pipe section of 1/2″ steel plate, 48″ in diameter and 10 feet long, being subjected to 1000 pounds' hydrostatic pressure. The test is being witnessed by Inspectors Conard, Anderson and Marshall, representing the cities of Boston, Detroit and Philadelphia, respectively. ¶ During the test the 1-1/4″ thick concave head completely reversed itself. The pipe shell was materially distorted, but the automatic electrically welded seams held perfectly — they never even sweat. The section was afterward subjected to 1250 pounds' pressure in an attempt to test the pipe to destruction, but with the same gratifying result. ¶ Biggs Electrically Welded Steel Pipe, 30″ to 72″ diameter, is in service on numerous important municipal water works projects. We should be pleased to discuss your present or pending requirements. Literature upon request.

THE BIGGS BOILER WORKS COMPANY

(30″ and larger steel pipe, welded or riveted)

Seneca and Kent, Akron, Ohio

New York Chicago Detroit

BIGGS Steel Pipe *Riveted and Welded*

BOILER WORKS CO. The Biggs AKRON OHIO

Do this much for the health of your community.....

WHAT is more important to the health of your city than water?...You build huge storage systems to provide plenty for everyone. You take elaborate pains to guard its purity. Yet, in spite of this, in many houses water comes from the faucets contaminated...*with rust!*

Two ways to end this rust menace lie within your power. First, you can use *rust-proof* service pipe of Brass or Copper. Second, you can urge property owners to install Brass pipe or Copper tubing in their homes at the time of building. Used in both places, Brass or Copper assures a full, constant flow of clear, healthful water.

Brass pipe and Copper tubing are not only the most satisfactory forms of household plumbing, they are also the most economical. Although their first cost is slightly higher than that of corrodible pipe, their long life and immunity to deterioration make them decidedly economical in the long run.

This association will be glad to supply full information about Brass pipe and Copper tubing, or cooperate with you in any efforts you care to make toward furthering their use in the homes of your community.

COPPER & BRASS
RESEARCH ASSOCIATION
25 Broadway, New York

Midwestern Office:	*Canadian Office:*	*Pacific Coast Office:*
Landreth Building	67 Yonge Street	Architects Building
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COPPER, BRASS, BRONZE—THE WORLD'S MOST USEFUL METALS

Centrifugal casting in these machines gives deLavaud pipe...

100% greater tensile strength

65% greater transverse strength

25% greater bursting strength

IN a series of strength tests on deLavaud Pipe, conducted by a disinterested testing laboratory, the results shown above represent the strength of deLavaud as compared with pit cast pipe.

While these percentages appear startling at first glance, a careful comparison of deLavaud metal with pit cast will help to convince you of their authenticity. For deLavaud Pipe metal will appear dense and extremely close-grained, while the structure of pit cast pipe metal will be coarse and crystalline.

deLavaud Pipe is made by pouring molten metal into a revolving cylindrical mould. Centrifugal force holds the iron against the mould and drives out slag and gas bubbles *with a force 40 times greater than gravity*. Thus deLavaud metal is dense and fine in structure. And, it is remarkably free from weakening impurities.

In addition, the action of the water-cooled deLavaud mould and the subsequent annealing further improve the physical properties and the microstructure of the metal.

Let us send you all of the facts and figures on deLavaud Pipe; also the deLavaud Handbook which gives useful information about types of joints and dimension tables.

Cast iron pipe made by this Company bears the "Q-check" trademark of The Cast Iron Pipe Research Association.

United States Pipe and Foundry Co., Burlington, New Jersey

Sales Offices: New York, Philadelphia, Pittsburgh, Cleveland, Buffalo, Chicago, Dallas, Birmingham, Kansas City, Minneapolis, Seattle, San Francisco, Los Angeles

0.01 PART PER MILLION CHLORINATION ACCURACY

with this new LaMotte Chlorine Colorimeter Set!

YOU CAN now eliminate all guesswork in the treatment of drinking water with this accurate LaMotte outfit. It actually detects differences of 0.01 part chlorine per million parts water, regardless of impurities! And yet the method entails nothing more than a simple comparison between special sealed Nessler Tube Standards and the prepared sample. The LaMotte Chlorine Colorimeter Set insures simple operation, accurate results — and economy! Order a set today, or write for complete information. Set, Complete, F. O. B. Baltimore, $25.00.

WATER ANALYSIS, whether for sterilization, purification or softening, requires special apparatus, standards and solutions. The chlorine colorimeter described above is only one of the many practical sets scientifically developed in our Research Laboratories. Colorimetric testing apparatus is now available for every type of water, sewage, and industrial water analysis. For use in such processes, a complete series of standards and solutions have been prepared in accordance with "Standard Methods of Water Analysis," published by The American Public Health Association. These are applicable not only to special LaMotte testing sets, but to all standard methods now in use. Write today for complete information.

The 5th Edition of our illustrated book, The A B C of Hydrogen Ion Control contains many practical suggestions on water works applications. A copy will be sent you upon request.

LaMotte Chemical Products Company

428 Light Street . . . . . Baltimore, Md.

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DRY FEED CHLORINATION

"Paradon DBP DRY FEED CHLORINATING SCALE."

In the DRY FEED method of chlorination, the chlorine gas is applied directly (direct feed) as a gas into the water or sewage chlorinated.

The DRY FEED method has many obvious advantages. A water supply for operation is unnecessary. This dispenses with the injector or similar mixing device. The number of parts is reduced approximately one third, and the construction, installation and operation of the chlorinator considerably simplified. A connection to waste for surplus water is not necessary. Freezing troubles are eliminated. Chlorine application may be made against pressures up to 25 lbs. per square inch w thout additional equipment. DRY FEED chlorination, other factors being equal, simplifies installation and operation. Approximately 500 PARADON DRY FEED CHLORINATORS are in successful operation.

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PARADON MFG. CO.
Arlington, N. J.

Paradon
CHLORINATORS
for—
City and Private Water and Sewage Systems, Industrial Plants and Swimming Pools.

Note: — The Paradon Chloriniser is available for the chlorination of very small water supplies, swimming pools, etc.

W-15 a

The Journal of the New England Water Works Association

is a quarterly publication, containing the papers read at the meetings, together with reports of the discussions. Many of the contributions are from writers of the highest standing in their profession. It affords a convenient medium for the interchange of information and experience between the members, who are so widely separated as to find frequent meetings an impossibility. Its success has more than met the expectation of its projectors; there is a large and increasing demand for its issues, and every addition to its subscription list is a material aid in extending its field of usefulness. ALL MEMBERS OF THE ASSOCIATION RECEIVE THE JOURNAL IN PART RETURN FOR THEIR ANNUAL DUES; to all others the subscription is four dollars per annum.

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